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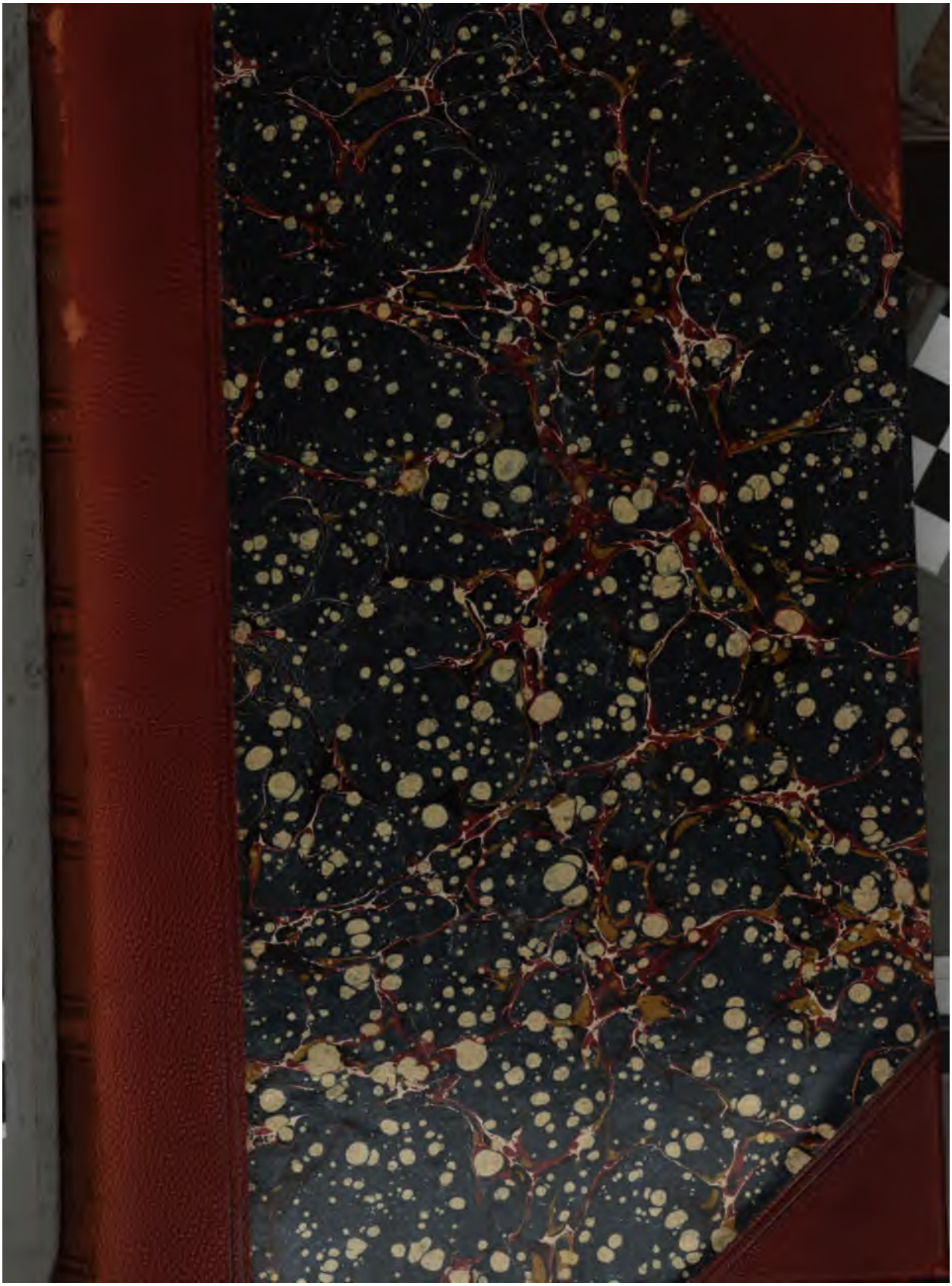

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TRANSACTIONS

OF THE

MANCHESTER

GEOLOGICAL SOCIETY.

EDITED BY

THE HONORARY SECRETARIES.

VOLUME THIRTEENTH,

1873, 4, 5.

MANCHESTER:

SOLD AT THE ROOMS OF THE SOCIETY, 36, GEORGE STREET.

1876.

212959

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ERRATA AND CORRIGENDA.

Page 22, line 25, add: Agassiz work now complete.
Page 130, last line but four, for *Canis vulpes*, read *Canis lupus*.
Page 276, line 15, for (fig. 21), read (fig. 20).
Page 278, line 4, for (fig. 20) read (fig. 21).

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OF THE

MANCHESTER GEOLOGICAL SOCIETY.

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TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART 1. VOL. XIII. SESSION 1873-4.

At the ANNUAL MEETING (adjourned from October 28th) of the members, held in the Lecture Room of the Literary and Philosophical Society, George Street, on Tuesday, 18th November, 1873.

JOHN KNOWLES, Esq., M.I.C.E., President, in the Chair.

Present:—Joseph Dickinson, F.G.S., John Aitken, F.G.S., J. E. Forbes, F.G.S., J. Plant, F.G.S., Kaye Knowles, Thomas Livesey, Clegg Livesey, J. S. Martin, J. Wild, S. Wild, and other members.

The circular issued by the Secretaries announcing this adjourned meeting having been read, the President called upon Mr. Plant to read the following Report and Balance Sheet.

REPORT OF THE COUNCIL.

Your Council have to express their regret that the day for the Annual Meeting as prescribed by the Rules of the Society, had to be postponed to the present date, in consequence of an oversight in not sending out the notices for the meeting; this will doubtless be willingly excused by the members when it is understood, that during the removal of the contents of the Natural History and Geological specimens from the Museum to The Owens College, the place is considerably upset, and all regularity in business

matters liable to be interrupted. On the other hand, this adjournment, however, has been in no way disadvantageous to the members of this Society, it has led to the fortunate assembling of the meeting in a far more convenient place—within the walls of a building almost venerable with time-honored associations with science, and with the names of men who are placed in the foremost rank of fame for their great labours and discoveries, in Physics, Chemistry, Geology, and other branches of modern science.—It is the fervent desire of your Council that the future career of the Geological Society may be influenced by these revered associations, and that its work may be stimulated with a spirit for progress which will lead to a right feeling amongst the members for the increase and prosperity of the Society.

Your Council have further to report that the long connexion which had existed between this Society and the late Natural History Society, extending over more than twenty years,—and in a modified form for the last four years with the joint-Commissioners of The Owens College and the Natural History Society—has at length been brought to a termination. In reviewing the events arising out of that connexion, it cannot be denied that the association between the governing bodies of the Geological Society and the Natural History Society, was scarcely at any time a happy one, but was too frequently a source of regretful misunderstanding, which undoubtedly affected the interests and prosperity of the Geological Society in many ways. The transfer of the specimens of Natural History, the Museum buildings, and other property belonging to the Natural History Society (which became defunct) to the Trustees of The Owens College—brought about the signing of an agreement in November, 1869, by which, reserving certain privileges for the future admission of its members, the Geological Society transferred its whole interest in its collec-

tion of fossils, minerals, and cases also to The Owens College, only retaining its library of books, maps, charts, sections, and other effects, as well as the right of holding its meetings in the room it had heretofore occupied in the Museum until the time when the Trustees ceased to occupy the building. The time has nearly elapsed, and before the end of the present year the Museum will be completely dismantled.

Your Council have had to take into their consideration a claim from the Museum Commissioners for the large amount of £144 12s. 0d. charged for Museum expenses from April, 1868. This matter has been brought to a satisfactory conclusion by the Museum Commissioners accepting the offer made by your Council, of what they deemed a just and fair amount in discharge of the claim, and the sum of £45 12s. 0d. will have to be paid over to the Treasurer of The Owens College. This transaction closes all the relations which have subsisted so long between this Society and the Museum in Peter Street.

In respect to the future meetings of the members of this Society, your Council have great pleasure in being able to report that they have entered into an engagement with the Council of the Literary and Philosophical Society for the use of its Lecture Room, and for accommodation for the library—together with the services of the resident attendant—for the yearly payment of £30. This will not be considered a large demand upon the funds, when it is brought to the experience of the members how much superior is the accommodation over that at the Museum, and how greatly the comfort of the members will be increased; whilst from the facilities afforded to the Secretaries the general business and interests of the Society will be in all respects better looked after. Your Council desire to express their high esteem

of the courtesy and kind consideration which they have received from the Council of the Literary and Philosophical Society in the negociations which have resulted in this engagement, and they trust all transactions between the two Societies will be conducted with a similar and mutual good feeling.

The present strength of the Society consists in 93 ordinary, 9 life members, and 10 honorary members, making a total of 112 members. During the session seven new members have joined the Society, five members have been taken away by death, and four have resigned.

The Council think it a duty to allude to the loss of one of its oldest honorary members—Professor Sedgwick, of Cambridge—who was made an honorary member of this Society at its establishment in 1838, more than a third of a century ago, when the science of Geology was yet in its infancy. Professor Sedgwick was held in universa esteem as a leading pioneer of Geological discovery, and respected as one of England's truest men of science. He died at the age of 88, on the 27th January, 1873.

The loss of Dr. Crace Calvert, F.R.S., a resident and old member of the Society, is deserving of mention. He was distinguished for his untiring pursuit of Chemistry, of which he had attained a profound knowledge, and bore a high reputation in England and on the Continent.

The meetings of the Society have not been numerously attended by the members during the past session, which may be reasonably accounted for by the inconveniences which have had to be submitted to during the removal of the Museum collections, your Council trust that this may be the last occasion which may require them to draw the attention of the members to the apparent want of interest

in attending the monthly meetings. The papers added to the printed transactions of the Society are considerably less in number and extent than in many former years, yet the subjects of those relating to Mining are both important and interesting to the owners and managers of collieries in this locality. This paucity in the number of papers is to be regretted, but it is capable of being remedied in the future by a more lively interest being taken by the members in the principal object of the Society, "the collection and diffusion of practical and theoretical knowledge respecting Geology and Mining."

The Library has received an accession by donations of the transactions of several kindred societies in Great Britain and abroad, and of a few recently published works by purchase. The Council are glad to be able to inform the members that in a short time the Library will be entirely collated, and recatalogued, previous to its being located in the Literary and Philosophical Society's Rooms; and there is a very fair prospect that the use of the Library will be largely augmented when it is placed in a condition that will make it more accessible, and better known to the members residing in the country.

The Council take this opportunity of calling the attention of their successors to the necessity of a thorough revision of the Rules, many of which are no longer applicable to the Society, after its seperation from the Manchester Natural History Society.

The Annual Financial Sheet, prepared by the Treasurer, shows a very favourable balance to the credit of the Society during the past year, but this balance will be subject to a considerable reduction by outstanding accounts to the amount of above £60, which were not prepared for presentation to the Treasurer in time to be included in his statement.

Henry Mere Ormerod in account with the Manchester Geological Society, from October 1st, 1872, to October 1st, 1873.

Dr. Cr.

RECEIPTS.

	£	s.	d.
To Balance brought down	104	2	11
,, Subscriptions for 1872-3	70	0	0
,, Arrears of Subscription	8	0	0
,, One Composition	10	0	0
,, Interest from Bank	2	9	7
,, Dividend from Birkenhead Railway	19	13	9
	£214	6	3
To Balance brought down	£157	19	8

Examined and found correct,

(Signed) JOHN HEELIS, AUDITOR.

7th November, 1873.

EXPENDITURE.

	£	s.	d.
By Books for Library	2	0	9
,, Reporters' Notes at Meetings	7	7	0
,, Printing Transactions and Stationery	16	5	2
,, Postages	6	12	8
,, Collector's Commission	3	18	0
,, Insurance on Library	0	3	0
,, Assistant to Secretary, one year	20	0	0
	56	6	7
By Balance carried down	157	19	8
	£214	6	3

The Stock belonging to the Society consists of £500 Birkenhead Railway Stock, standing in the names of Henry Mere Ormerod and Andrew Knowles.

(Signed) HENRY M. ORMEROD, TREASURER.

30th October, 1873.

NEW MEMBERS, 1873.

Feb. W. E. Garfott, Engineer, Dukinfield.

March. Clifford Smith, Parkfield, Swinton.

April. Alfred Pilkington, Edward Pilkington, } Clifton and Kersley Collieries.

Oct. Jos. S. Martin, Assistant Inspector of Mines, Park Villas, Prestwich.

„ James Tonge, Hulton Collieries, Bolton.

„ J. F. Seddon, Great Harwood Collieries.

MEMBERS RESIGNED.

H. Bridge, elected 1868.

William Evans, elected 1867.

J. C. Rivett, elected 1870.

Thomas Turner, F.R.C.S., elected 1844.

MEMBERS DECEASED.

Professor Adam Sedgwick, LL.D., F.R.S., hon. member.

Sir Oswald Mosley, Bart., elected 1859.

Dr. Frederick Crace Calvert, F.R.S.

William Ross, J.P., Pendleton. Elected 1838.

William Harter, Hope Hall, elected 1838.

LIST OF PAPERS AND SUBJECTS BROUGHT BEFORE THE ORDINARY MEETINGS IN THE SESSION.

1872.

Nov. Knowles John, M.I.C.E., President, "On Fires in Collieries," with special reference to the recent fire in the Rams mine, in Pendlebury.

Dec. Whaley Thomas, "On the Fire in the Norley Colliery, near Wigan."

,, Plant John, F.G.S., "On certain Neolithic weapons brought from Venezuela, by Mr. Spence."

1873.

Jan. "Discussion on the Black Burton Coal Field, Yorkshire."

Feb. "Discussion on the Section of Rocks through the Summit Tunnel at Blackstone Edge."

March. Binney E. W., F.R.S., Vice-President, "Description of Mr. W. A. Purdon's Section of the Blackstone Edge Tunnel, which was presented to the Society in 1842."

April. Dawkins W. Boyd, F.R.S., "An account of the Members' Excursion up the Valley of the Irwell from Clifton to Radcliffe."

,, Aitken John, F.G.S., "Notes on an Ossiferous Cavern in the Carboniferous Limestone at Waterhouses, Staffordshire."

May. Plant John, F.G.S., "On Human and Animal Remains in Caves in North Lancashire."

June. Aitken John, F.G.S., "Remarks on some fine specimens of Slickensides, from the Millstone-grit exposed in Todmorden valley."

ADDITIONS TO THE LIBRARY.

By Purchase.

1. Bristow and Etheridge, "Table of British Sedimentary and Fossiliferous Strata," folded in a cover.
2. Hull E., F.R.S., "The Coal Fields of Great Britain," last Edition.
3. Hunt Robert, F.G.S. "Mineral Statistics of Great Britain, for 1871."
4. Jukes J. Beete, M.A., "Manual of Geology," edited by Professor Geikie, new Edition.
5. Palmieri Professor Liugi, "The Eruption of Vesuvius in 1872," edited with additions by Robert Mallett, 1873.
6. Phillips Professor John, "Vesuvius," 8vo., 1869.
7. Palæontographical Society's Publications for 1873.

By Donation.

Christiania, The Royal University of Norway.

1. Kjerulf Professor Theodor, "On Ice Marks and the Glacial Formation and Terraces in Norway," 4to. Map, pp. 101 (in Norske).
2. Helland and Münster, "Layers of Pyrites in certain States in Norway," 4to., 3 plates, pp. 97 (in Norske).
3. C. de Seue and S. A. Sexe, "The Snowfields and Glaciers of Instedal," 4to., Map and 9 photographs, pp. 55 (in French).
4. Sexe Professor S.A., "On the Rise of Land in Scandinavia," 4to., pp. 17 (in English).
5. "Glacier Movements," pp. 8 (in Norske).
6. Kjerulf Th. Professor, "On the Geology of the district about Trondhjem," royal 8vo., Map, pp. 79.
7. "On Turf, Peat, and Bog," pp. 10 (in Norske).
8. Patterson Karl, "Profil gjeunem Reisenelvens," pp. 7.

Dickinson Joseph, F.G.S., "Three Reports of H.M. Royal Commissioners on the Supply of Coal in Great Britain," with a portfolio of 15 Maps and Sections accompanying the Reports. Folio, 1871.

Glasgow, The Geological Society of. "The Silurian Brachiopoda of the Pentland Hills," by T. Davidson, F.R.S. Part 1, 4to.

,, "Transactions of the Society." Vol. IV. Parts 1, 2, 3.

London, The Geological Association of. "Proceedings from November, 1872, to October, 1873."

,, The Geological Society of. "Quarterly Journal." Nos. 112, 113, 114, 115, 116, for 1872-3.

,, "Abstracts of Proceedings." Nos. 255 to 272, 1873.

Edinburgh, The Geological Society of. "Transactions." Vol. II. Part 2. November, 1872, to May, 1873.

South Wales Institute of Engineers. The Proceedings of the. Vol. VIII. Parts 1 to 5, 1873, 8vo.

Liverpool, "Geological Society of." Abstract of Proceedings for 1872-3. 14th Session, 8vo.

Ireland, The Royal Geological Society of. "Journal." Vol. III. Part 3 to June, 1873, 8vo.

Manchester, The Literary and Philosophical Society of. Proceedings. Vol. XII. 1872-3, 8vo.

Canada, Selwyn, A. R. C., Director of the Geological Survey. "Reports of Progress, for 1871-2." Royal 8vo., pp. 154. "List of Publications of the Geological Survey of Canada." 1873.

Marsh, Prof. O. C., "On the Structure of the Mosasauroid Reptiles." pp. 21. "Remains of Pterosauria, &c." "Description of a new Cretaceous Bird "Hesperornis Regalis."

Newberry, J. S., Chief Geologist to the State of Ohio, U. S. "Report on the Progress of the Geological Survey in Ohio in 1870, with a case of five maps of grouped sections, 8vo. 1871.

Warwickshire, Natural History, &c., Society. Annual Reports for 1871-2-3.

Whitaker Wm., List of Works relating to the Geology of the Hampshire Basin.

On the motion of Mr. J. E. Forbes, seconded by Mr. J. Aitken, the Annual Report was unanimously adopted and ordered to be printed.

On the motion of Mr. J. Dickinson, seconded by Mr. K. Knowles, it was resolved unanimously—That in the opinion of this meeting it is desirable that the office of President be held for *one* year only, and not for two years in succession as stated in Rule XXVI., and that this proposed change be now adopted and carried out in future.

The following gentlemen were elected officers and members of the Council for the ensuing year :—

President.

THOMAS KNOWLES, Wigan.

Vice-Presidents.

EDWARD WILLIAM BINNEY, F.R.S., F.G.S.
JOSEPH DICKINSON, F.G.S.
JOHN KNOWLES, M.I.C.E.
JOHN AITKEN, F.G.S.

Hon. Curators.

G. C. GREENWELL, F.G.S.
THOMAS ALCOCK, M.D.

Auditors.

JOHN HEELIS.
THOMAS LIVESEY.

Secretaries.

JOHN EDWARD FORBES, F.G.S.
JOHN PLANT, F.G.S.

Treasurer.

HENRY MERE ORMEROD.

Of the Council.

WILLIAM BRYHAM.
SAMUEL CROWTHER.
JOHN CROSS, (WIGAN).
ROBERT D. DARBISHIRE, B.A., F.G.S.
W. BOYD DAWKINS, M.A., F.R.S., F.G.S.
HERBERT FLETCHER.
CHARLES HARDWICK.
WILLIAM HENRY JOHNSON.
KAYE KNOWLES.
CLEGG LIVESEY.
CLIFFORD SMITH.
JOHN WILD.

The Chair having been taken by Mr. J. DICKINSON, it was resolved unanimously—That the thanks of the meeting be given to the retiring President and Council.

LIST OF MEMBERS,

DECEMBER 1ST, 1873.

The Names of Honorary Members are printed in *Italics*.

* Members who have compounded for the Annual Subscription.

Year of Election.	
1840	*Agassiz, Louis*, M.D., LL.D., Professor of Natural History, Cambridge, Massachussetts.
1863	Aitken, John, F.G.S., Bacup.
1862	Alcock, Thomas, M.D., Oak Field, Ashton-on-Mersey.
1865	Ashworth, Edward, Stag Hills, Waterfoot, near Manchester.
1864	Ashworth, John, Rose Hill, near Bolton.
1866	Bamford, J. B., Mining Engineer, Rochdale.
1859	Barr, William Roby, F.G.S., Park Mills, Stockport.
1859	Bazley, Sir Thomas, Bart., M.P., Cyford Park, Stow-on-the-Wolds.
1861	Beswicke, William, South Parade, Rochdale.
1838	Binney, E. W., F.R.S., F.G.S., 55, Peter Street, Manchester.
1867	Bolton, H. H., Newchurch, near Manchester.
1866	Brierley, Joseph, Civil Engineer, Blackburn.
1859	*Brongniart, Adolphe, F.G.S.* Professor of Botany, Jardin des Plantes, Paris.
1864	Brooke, William, F.G.S., Hale Carr, Altrincham.
1861	Brooks, Thomas, Sunnyside, Rawtenstall.
1859	Bryham, William, Rose Bridge Colliery, Wigan.
1861	* Buccleuch, His Grace the Duke of, Whitehall Gardens, London.

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OF THE

MANCHESTER GEOLOGICAL SOCIETY.

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TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART 2. VOL. XIII. SESSION 1873-4.

The OPENING MEETING of the Session was held at the House of the Literary and Philosophical Society, on Tuesday, the 23rd December, 1873, when above thirty members were present.

Mr. THOMAS KNOWLES, President, in the Chair.

The Honorary Secretaries made an announcement to the meeting that the Council had taken into their consideration the question of adding to the present list of the Honorary Members, which had been greatly reduced during the last ten years, and they had unanimously recommend the following gentlemen for election as Honorary Members of the Society:—

Owen, Richard, M.D., D.C.L., LL.D., F.R.S., &c., Sheen Lodge, Richmond Park, S.W.

Harkness, Prof. Robert, F.R.S., F.G.S., Queen's College, Cork.

Hawkshaw, Sir John, Knt., F.R.S., F.G.S., &c., 33, Great George-street, Westminster, S.W.

Ormerod, Geo. Wareing, M.A., F.G.S., Brookbank, Teignmouth.

Ramsay, Prof. Andrew C., LL.D., F.R.S., &c., Director-General of the Geo. Survey of the United Kingdom.

Hull, Prof. Edward, M.A., F.R.S., &c., Director of the Geo. Survey of Ireland, 14, Hulme-street, Dublin.

Geikie, Archibald, F.R.S., F.G.S., of L. and E., Director of the Geo. Survey of Scotland, Victoria-street, Edinburgh.

Agassiz, Prof. Alexandre, Cambridge, Boston, Mass., U.S.

Woodhouse, John Thomas, F.G.S., M.I.C.E., Midland-road, Derby.

Forster, Thomas Emerson, M.I.C.E. 7, Ellison Place, Newcastle-on-Tyne.

Morton, George Highfield, F.G.S., 21, West Derby-road, Liverpool.

Hawkins, B. Waterhouse, F.L.S., F.G.S., Century Club, East 15th Street, New York City.

Since the last meeting of the Society, news had reached England of the death of Professor Louis Agassiz, of Cambridge, Massachussetts, who had been an Honorary Member of this Society from the year 1840. It was at the Meeting of the British Association at Manchester, in 1842, that Professor Agassiz was invited to devote his attention to the subject of the fossil fishes of the old red sandstone; and in 1844, when this important monograph was published, the author stated upon the title, "Une ouvrage ridigé a la demande de l' Association Britannique pour l' avancement des sciences et presentè par extraits a sa réunion à Manchester, en 1842." The Library of the Society possesses a copy of Professor Agassiz's great work, entitled "Recherches sur les Poissons Fossiles" (unfortunately incomplete in the illustrations), Monographie des Poissons Fossiles du Vieux Grès Rouge," and a portion of his elaborate work on the "Fresh Water-fishes of Central Europe." In Agassiz the world has lost a philosopher and naturalist whose name will be remembered along with those of Buffon, Cuvier, and Humboldt, and of whom both his native Switzerland and his adopted country might well be proud.

The President, after taking the Chair, said: I must thank the members of the Society for the honour they have

conferred upon me by electing me President for the ensuing year. I assure you it is an honour I little deserve; for, although having been a member for some time, I have attended the meetings very badly. I have, nevertheless, read in the printed reports the discussions that have taken place with no little interest, and no little instruction, they have not only been a source of pleasure, but I have found them of great use to me in my practical mining operations. On the present occasion I will merely thank you for the honour you have done me, and assure you that it will be a pleasure to me, at all times, to do all in my power to further the interests of the Geological Society of Manchester.

Mr. Joseph Dickinson, F.G.S., Inspector of Mines, exhibited some of the saliferous marls and marlstones obtained during an inspection into the causes of the landslips in the Salt District of Cheshire. In a paper upon the subject, Mr. Dickinson said:—

ON THE SALIFEROUS STRATA.

By Joseph Dickinson, F.G.S.

Some of you are aware, that in consequence of a representation made by the Salt Chambers of Commerce, in 1871, I was directed by Her Majesty's Government to make inquiry into the state of the landslips in Cheshire, caused by the working of rock-salt and the pumping of brine, which, it was alleged, involved damage to property, and risk to human life.

The report which I have made as the result of my inquiry having been presented to Parliament, and printed; and as I am presenting a copy of it to this Society, I need only state that some of the subjects to which it refers, such as the details of the saliferous strata, the mining of rock-salt, and the flowing away and pumping of brine, with the consequent

landslips, and alterations of the earth's surface, which are to be seen in full operation in Cheshire and Worcestershire, and may still be traced by occasional landslips and sinkings, southwards from Middlesbrough-on-Tees, and between Barton Mere, near Southport, and the south-shore of Blackpool, may hereafter form interesting matter for discussion; but at present it is only my intention to show you some specimens of the principal strata with which the rock-salt beds are associated, and to invite you to an expression of opinion whether the conclusions which I have arrived at as to the position of the rock-salt beds in the geological series is a correct one.

At the commencement of my inquiry, I found that it was essential to determine the exact geological position of the rock-salt strata, otherwise no idea could be given as to the probable area over which the landslips might extend. This will be more readily understood when I state that the maps of the Geological Survey do not indicate either the present or previous extent of the rock-salt, but only give a few outcrops of what are called shaley marls, which, on examination and comparison with what are found in the rock-salt mines, I find are the true saliferous marls and marlstones; and from the fact that the latest publication that had appeared upon the rock-salt strata, "On the New Red Sandstone of Cleveland, and the Rock-Salt discovered in it," by Mr. W. H. Peacock, published in the "Transactions, of the Cleveland Literary and Philosophical Society," set forth in effect that there was but *one* rock-salt formation in England, which view, it was understood, had been endorsed by high geological authority. The assuming of a limit, therefore, to which the landslips might extend depended altogether upon whether that view was correct or not; and it forced upon me the fixing of the positions which the rock-salt holds in the series. The details of my investigation under this head are set forth

in my Report to Parliament, with the names of the eminent geological authorities upon which they are based; the result of which is the conclusion that there are *two* principal rock-salt formations in England, of which that of Cheshire is the upper, and that of Middlesbrough the lower. Indeed, were it otherwise, the 300 yards of red sandstone proved at Middlesbrough above the rock-salt, as well as the red marls above that red sandstone, would all have to be added to the immense thickness—nearly 1,000 yards—of red rocks already known in the series.

The division of these red rocks which I have taken for Lancashire and Cheshire is as follows, in descending order:—

		Feet.
1.	Keuper, or saliferous, in Cheshire and South and West Lancashire, consisting of variegated saliferous marl and marlstone, with thin plates of gypsum, and thin beds of limestone, together with 210 feet in different beds of rock-salt	600
2.	Lower Keuper, or Red Marls, consisting chiefly of red marl, with two beds of variegated sandstone.	500
3.	Bunter, or Upper Red Sandstone, consisting of white and brown sandstone, with quartz pebbles, and flakes and thin divisions of marl, and and a few thin divisions of mica.	900
4.	Red Marls, as seen in the valley of the Irk, at Manchester, &c., consisting of variegated marls, with fossiliferous limestone	210
	Lower New Red Sandstone, as quarried for moulding sand in the valley of the Irk, at Manchester, consisting of soft red sandstone, partly variegated	600

These rocks are known by various names. Many practical miners, who have not yet found the necessity of dividing

them, group the whole together under the name of the Red-rocks, or New Red Sandstone. In some instances, No. 3, with 2 and 1 above it, are called the Upper New Red Sandstone; and No. 4 the Lower New Red Sandstone; whilst more recently the name Trias has been introduced for the former, and Permian for the latter; but now and then it is found that the term Permian is used without any more distinction being intended than what is conveyed by the original name of Red-rocks.

The Geological Surveyors, it appears, lay it down that the Trias and the Permian are unconformable with each other, and give reasons for that conclusion. In the investigations which I have found it requisite to make for my purpose as to the landslips, the question of unconformability has not presented itself, nor has any unconformableness appeared between the two, except such as may be explained by natural changes in thickness of strata, and the disappearance of immense beds of rock-salt by solution from amongst the strata.

One other point which I have noted in my Report is with reference to the red marls of North Wales, as sunk through in the upper part of the shafts of Hafod-y-bwch Colliery, in Denbighshire, which have hitherto been classed as Permian. These, I have ventured to suggest, will probably prove to be carboniferous marls, corresponding with similar thick beds which divide the North Staffordshire coal-field. It was not until Mr. D. C. Davies, F.G.S., of Oswestry, called attention to the coal-field of Ifton, in Shropshire, being above the Permian, and a discussion thereon before this Society, headed in the Transactions, "Coal in the Permian,"* that I carefully noticed the marls at Hafod-y-bwch and the Permian which overlies them on the dip, and as sunk through at Oswestry,

* Vol. xii., p. 29.

that I found there is a difference between the two, which justifies my assumption that they are not identical; the marls of Hafod-y-bwch being nearly all clay, whilst the Permian on the dip and at Oswestry, is divided by sandy beds. If this view is correct, a recasting of the extent of the Permian will be required on the geological survey maps.

On the motion of Mr. J. KNOWLES, seconded by Mr. T. LIVESEY, the thanks of the meeting were voted to Mr. Dickinson for his paper.

The CHAIRMAN conveyed to Mr. Dickinson the thanks of the Society for a copy of his "Report upon the Causes of the Landslips in Cheshire," which he had presented.

Mr. AITKEN said: Mr. Dickinson referred, in his paper, to some red rocks which occur near Oswestry, these rocks, I believe, have been described by Mr. D. C. Davies, to whom reference has been made, as belonging to the Permian; and in those beds, I believe, certain seams of coal have been discovered. I notice that Mr. Davies has recently written a paper upon the subject, a copy of which he kindly sent to to me; and it appears that, in consequence of that or some other information, Mr. Dickinson has visited Oswestry and examined the beds, alleged by Mr. Davies to have been of Permian origin. I have been in the district, but though my opportunities of examining the beds were slight, I suspected that they were not Permian but that they were coal-measure beds, in which the alleged Permian coal was found. I would like to ask Mr. Dickinson, as he has made a careful inspection of them, to what formation he would refer them? I rather gathered from his paper that he thought they belonged to the coal measures.

Mr. Dickinson: I believe the red deposits at Oswestry are Permian; and so I have stated in my paper. It is the red marls occurring further north, which become overlaid by these Permian beds, that I consider to be carboniferous marls; but the red rocks at Oswestry are, in my opinion, true Permian.

Mr. Dickinson then exhibited and gave a detailed explanation of the specimens from the rock-salt strata, consisting mostly of marlstones, or the particular kind of marl with which rock-salt is associated, with reference to a peculiar flat marlstone exhibited, he explained that the rock-salt in the place whence it was taken had probably, ages ago, been dissolved, and had flown away into the sea (probably causing its saline character), and in all such places he found more or less evidence of sliding, as though their overlying rocks had slid away, causing streaked markings upon those beneath. In other places he found beautiful casts of cubes, the form of rock-salt crystals as obtained by slow evaporation, some of these cubes were very much larger than others, the rule was; the slower the evaporation the larger the crystal; the more rapid the evaporation the finer the salt.

Amongst the specimens exhibited were some of rock-salt, of different qualities and degrees of fineness; and crystals of salt, which had been crystallized from brine lying upon the floor of one of the Cheshire salt mines, where the evaporation, taking place in the dark, had been slow, these crystals were of the true cubical form, but, Mr. Dickinson said, much smaller than those formed by slow evaporation in a pan. Mr. Dickinson said he had other specimens of the strata with which these rocks and marlstones were associated, for instance, some new red sandstones, procured from Middlesbrough, as well as from the Alderley Edge copper mine, which the Geological Survey classed as Keuper. Instead of being Keuper, he believed it

would ultimately be found that this was a part of the Bunter Sandstone. It was quite distinct from those two upper beds of sandstone which are to be traced, at many points, in the Keuper; and it was apparently a bed which extended across the whole salt field. It seemed to have formed the sands at Bowdon and Altrincham, and was also to be seen where the marls are still remaining, at Warburton.

Mr. PLANT: I am not quite clear whether my ideas about the division between the true Trias formation, as it exists in Lancashire and Cheshire, apart from the Permian, are at fault, or whether it is that Mr. Dickinson, in his paper, has lost sight of the very clear and well defined line that geologists have discovered to exist, separating these two important formations. The separation between the true Permian, of which specimens are before us, and any of the beds of either the Bunter or the Keuper formation, is, without doubt, very clear and well defined in some places, even in Lancashire. At Collyhurst, for instance, we see the line of separation between Permian marls, which are fossiliferous, containing species of *Schizodus*, *Bakevillia*, and other shells, which never yet have been obtained from the overlying strata belonging to the Triassic series, that, of itself, is sufficient with all our eminent geologists to mark the true definition between these two great formations. I think, also, that Mr. Dickinson, in alluding to the Middlesborough deep sinking, stated that, in consequence of the enormous depth at which there was discovered, a great bed of salt, therefore the salt formation is separable into two great divisions—an upper in Cheshire and a lower in Yorkshire. That may appear to be so, taking a section of each sinking only into account; because it so happened, that the strata passed through appeared to show two beds of salt lying at considerable distances one from the other; but the deposition of salt, wherever it can be examined

entirely, lies rather in bedded masses of limited area. The Middlesbrough sinking displayed only a section of the centre of a large mass of rock-salt; whereas, if the sinking had been made half a mile on either side, might have missed the salt altogether. Mr. Dickinson, in his paper, referred to the markings upon a flat piece of marlstone, the one Mr. Dickinson exhibits as an illustration of what is called Slikensides. It would be impossible for anybody visiting a quarry where the Triassic, especially the Keuper, beds are worked without finding the beds separated by marls of this character, exceedingly thin plates, and covered over with what have been adjudged for at least half a century to be nothing more nor less than ripple markings, the markings like those upon this specimen, I think, are not to be explained by a slipping of the rocks; and still more, I think, would there be a sound objection to the idea that the "salt has been dissolved away from these rocks and flown into the sea." That would be a reversal of the operations of nature under which we have been always taught to believe the salt beds and the rocks themselves were deposited. The collection is one of considerable interest, from the wide area over which the specimens have been procured, and it gives a very good idea of the characters that belong to each; these specimens are all, with one exception, non-fossiliferous. Now, in Warwickshire, Worcestershire, and Leicestershire, the same beds of Keuper, or at least what are probably equivalent to those beds, are all fossiliferous—not very largely so; but they contain specimens of *Estheria*, fish teeth of *Hybodus*. *Acrodus*, and the feet markings of reptilians. Cheshire is not a prolific representative of the Triassic beds in which these fossils have been deposited. Mr. Dickinson also alluded to the gypsiferous deposits; but not much information was given to show how they were related to

the deposits of salt; in other parts of England gypsum is found deposited, almost identical in geological position to the salt of Cheshire, yet it frequently, as it were, replaces the salt with a deposit of fine gypsum, as in Derbyshire and Leicestershire.

Mr. Dickinson: I should say, with reference to what Mr. Plant has just stated, that I have not by any means overlooked those fossiliferous beds which divide the two —that is, the Permian from the Trias above it.

Mr. Plant: I did not mean to say that you had overlooked it; but you called it the lower, as distinguished from the upper, red sandstone; giving to the one 600 feet and to the other 900 feet. I understood your own idea to be that they should not be separated—that the lower red rocks were part of, and conformable to, the upper rocks.

Mr. Dickinson: I did not overlook that important division to which Mr. Plant has called attention, but I specially put down the thickness of it at 210 feet, the thickness fixed for it by Mr. Binney; and I stated that it contains certain fossils; here are the fossils from this neighbourhood to show to you. I have, amongst the rest, a specimen of the same kind of fossil which I took about one mile north of Larne, in the North of Ireland, from an out-crop that corresponds with the Permian, and as, I believe, identical with the rocks that Mr. Plant thought I had omitted. Then, having named these fossils, lying in that one division which corresponds, apparently with the magnesian limestone—extending from Tynemouth Castle, Northumberland, southwards nearly as far as Nottingham—having named the fossils which are found in this particular part of these red rocks, there is not, so far as I have observed, or so far as I have heard—and I have inquired of many persons who have been among the rock-salt mines for years—there has never been a fossil found in any part of the saliferous formation. It is

entirely devoid of fossils; and all that I can detect are these pseudomorphous salt cubes, or dendritical impressions, as Professor Sedgwick called them, and this sliding of the rocks over one another; that they have slid there can be no question. In many places where the rock-salt is now gone, having been dissolved into brine and flowed into the sea, the overlying rocks are twisted into beautiful contortions, and sometimes into perfect arches. Some of the Lias limestone quarries give the best illustrations of the effect which the solution of the salt has produced upon the overlying beds. In quarries near Rugby beautiful examples are now to be seen, and there are others in the county of Durham which have never, I believe, been attributed to the disappearance of rock-salt, but which, to my mind—having gone minutely into the subject—are attributable to nothing else.

Mr. Aitken said it was possible that what Mr. Dickinson described as contortions might be ascribed to subsidence. The specimen now produced did not show any of the characters common to what he (Mr. Aitken) understood as Slikensides. It was difficult to believe that they could be so. The rock salt, being dissolved, would cause the subsidence of the superincumbent strata, but not a lateral sliding. He could not, for his own part, conceive how the furrows could arise from that cause; and the specimen did not, in his opinion, prove it.

Mr. Dickinson said he had not in any one of the mines which were open, or on any of the marlstones from those mines, noticed those groovings which he supposed had been made by the rocks sliding against one another; but in the out-crops of the marlstone, where apparently the rock-salt had been dissolved, years ago, there were groovings and also those dendritical impressions to which he had referred.

Mr. Aitken pointed out that the lines upon the specimen produced were waved, an appearance which he conceived to be impossible in Slikensides.

Mr. Dickinson said that in some of the Cheshire land-slips, the process was gradually extending over miles of country; in places the sinking took the form of round holes, one, described in the report, had become about 100 feet deep; and there are other sinkings of various shapes. In that case there must be friction taking place in all directions, it could not always be in a straight line.

Mr. Plant said there was another objection to Mr. Dickinson's theory, if these shales were separated, the divisions, however fine, would all present the same wave-like markings that established the fact of their being ripple marks.

Mr. Dickinson said he hoped soon to see the original out-crop of these rock-salt beds, and the outcrop of the saliferous marlstones laid down on the geological maps of the Government Survey.

Mr. Plant said it might be that the saliferous marls of Cheshire, which appeared to be devoid of fossils, had not been minutely examined, there were footprints of the *labyrinthodon* and plenty of reptile impressions at Stourton and Lymm.

Mr. Dickinson: In the saliferous marls and marlstones I have not known a single fossil to be found. At Lymm, where the so-called marks of the *labyrinthodon* are found, the rocks are by no means in the position of these marlstones which I am now showing you. They lie far below them

Mr. Plant: I would like to ask Mr. Dickinson's opinion of the theory that all the meres of Cheshire had been formed, at a comparatively recent period, by the disappearance of beds of salt nearer to the surface than those now worked for brine. The one at Combermere, which is of great depth, was stated some fifty years ago to be slightly saline in its character.

Mr. Dickinson: There can be no question but that Combermere and the range of meres around Northwich, Budworth, &c., to which I allude in my report, giving the dates in some instances when their formation commenced, have been formed after the solution of rock-salt. Budworth and Pickmere meres are, to my mind, evidently upon the outcrop of the main top bed of the rock-salt of Cheshire: the Rostherne mere, I consider, was formed by the solution of rock-salt in the bottom bed. With regard to the meres three miles south of Southport—Barton mere and others—you will find it recorded in Baines's "History of Lancashire," and elsewhere, that until recent years there was a great flow of pure brine at these places.

Specimens Exhibited.

Mr. J. Dickinson exhibited an extensive collection of rock specimens to illustrate his paper.

Mr. J. Plant exhibited specimens of Keuper marls from Leicester, Warwick, and Derbyshire, with teeth of *Acrodus*, Icthodorulite of *Hybodus*, Cololithic markings, and *Estheria minuta*.

Mr. J. Graham Williams, of Penllyn, Pwllheli, exhibited some decomposing Cambrian schists, on which were found considerable quantities of a powdered black oxide of manganese. The schists bore also on their surfaces layers of spicular crystals of quartz; they occur in the schists near Pwllheli.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART 3. VOL. XIII. SESSION 1873-4.

At the ORDINARY MEETING of the members, held at the House of the Literary and Philosophical Society, George Street, on Tuesday, 27th January, 1874.

JOSEPH DICKINSON, F.G.S., Vice-President, in the Chair.

There were twenty members present.

The following donations were announced:—

From F. V. Hayden, U. S. Geologist.

"Synopsis of New Vertebrata from the Tertiary of Colorado," pp. 20.

"Lists of Elevations, West of the Mississippi," pp. 48.

"Meteorological Observations during 1872 in Utah, Idaho, and Montana," pp. 120.

From the Association.

"Proceedings of the Geologists Association." No. 4, Vol. III. Jan., 1874.

From the Society.

Abstracts. "Geological Society of London." Nos. 274-5-6-7.

From the Society.

"Proceedings of the Literary and Philosophical Society of Manchester." Nos. 5, 6, 7, 8, 1873.

From Mr. J. Mackenzie, F.G.S., Sydney.

"First Report on the Coalfields of Victoria, N. S. W.," with Sections.

The CHAIRMAN read a list of the names of gentlemen recommended by the Council for election as Honorary Members of the Society, printed in the proceedings of the last meeting. The list was unanimously approved and adopted.

Mr. J. AITKEN then read the following paper :—

NOTES ON THE DISCOVERY OF A NEW FISH, OF THE GENUS *ACROLEPIS, AG.*, IN THE MILLSTONE GRIT, NEAR HEBDEN BRIDGE, YORKSHIRE.

The thick mass of coarse grits, with their intercalated beds of black and brown shales and occasional thin bands of limestone and calcareous grits, which constitute the Millstone-grit series, and which form so important a feature on the eastern borders of Yorkshire, have, until within a short period been looked upon as possessing but a scanty and imperfect representation of the animal life of the period.* More extended observation, however, has revealed the fact that the formation is by no means barren of fossil remains, some of the thick beds of argillaceous deposits, which form so considerable a proportion of the series in the locality to which these remarks more particularly apply, being charged not only with an important display of fossils numerically, but also representing a fine suite of genera and species.

It is also found that the calcareous element enters more largely into the composition of the Millstone-grit series of

* In making this statement, I purposely exclude the grits which overlie the Carboniferous Limestone on the Welsh border, in the neighbourhood of Oswestry, Llangollen, Bristol, &c., which are known to contain a comparatively rich fauna, for reasons given by Mr. J. H. Green, F.G.S., in vol. 4, page 11, and by myself in vol. 6, page 263, of the Geological Magazine.

rocks than was formerly supposed, more particularly amongst its lower members. In the Presidential Address I had the honour of delivering to this society on the 30th of November, 1869, I pointed out the existence of an important stratum of calcareous grit in the neighbourhood of Hebden Bridge, and expressed a hope that fossil remains might reasonably be expected to be found therein, that hope has however, so far, not been realized. It is, nevertheless, satisfactory to know that since that time Mr. Tiddeman, of the Geological Survey, has discovered, about two miles south-east of Clapham, in Yorkshire, and kindly pointed out to me, a bed of dark grey limestone, about 10 feet in thickness, low down in the Millstone-grit series, abounding in small encrinal columns, and other Carboniferous limestone fossils, having a texture and appearance so like the true Carboniferous limestone as to be almost undistinguishable from them. The occurrence of these calcareous deposits in the lower part of the Millstone-grit series, and the entire conformity of the whole formation, not only amongst its several members, but also with the Carboniferous limestone below and the coal measures above, points to a slow and gradual change of conditions, extending over a wide area and lasting during an immense period of time, in which variations in the relative level of the land and sea occurred. The deep sea conditions of the Carboniferous limestone period giving place to and being succeeded by a state of things unmistakably pointing to the prevalence of shallow seas, or large estuaries, in which were deposited, in alternating layers, coarse sandy material and argillaceous mud, varied in the subordinate layers by occasional thin bands charged with calcareous matter.

That no violent or cataclysmic change occurred, separating the Yoredale from the Millstone-grit periods, is also proved by investigating the fauna of the two formations. In the neighbourhood of Hebden Bridge, where the two series of

deposits can conveniently be examined and studied, it will be found that a remarkable similarity of life forms pervade the whole, such fossils as the Goniatites, Nautilus, Orthoceras, Posidonia, Aviculopecten, and fish remains being common to both, and in much the same proportion; true it is that a few forms are confined to one or other of the formations so far as yet known, but this apparent variation would in all probability disappear under a more careful observation, most of the beds having only as yet been subjected to very cursory examination at their outcrops, whilst others have received scarcely any attention whatever. The unexpected treasures which those have yielded which have been thus only partially examined, leads to the confident hope that other important discoveries may yet be made in other members of the series.

During the execution of the works carried on by the Corporation of Halifax, for conveying water from the Widdup Valley to that town, by a tunnel excavated through Wadsworth Moor, in the direction of W. and E., about two miles north of Hebden Bridge, and at a depth of 384 feet from the surface, a bed of fine black laminated and highly fossiliferous shale was encountered, having all the appearance and characteristics of a true coal measure shale—indeed so striking is the resemblance, that credulous but badly advised people have on several occasions been induced to embark in the fruitless effort of discovering coal therein, with of course the usual disappointing results—on splitting open this shale the surfaces reveal the presence of multitudes of fossils, some of which are very perfect and in a good state of preservation, whilst others exhibit a mass of fragments of all sorts in utter confusion, Goniatites and Aviculopectens prevailing. A number of modern concretions are also found within the shale, some of which are rich in fossils in considerable variety, from these balls the largest proportion of the fish remains, the most perfect shells, and other forms have been

obtained. From the debris brought out at the various shafts, with the kind assistance of Mr. Thomas Ashworth, of Hebden Bridge (who has shown very commendable assiduity in collecting fossils from this locality, and to whose kindness I am deeply indebted), I have been able to determine seven species of Goniatites, three of Nautilus, two of Orthoceratites, two of Aviculopecten, two of Posidonia, one gastropod, (Melania,) one Productus, "*P. semireticulatus*," a doubtful crustacean, and six genera of fishes. The nodules from whence most of the fossils have been obtained are generally very hard, breaking with a concoidal fracture, rendering it difficult to separate the fossils from the matrix, and often leading to their inadvertent destruction.

The stratum referred to, occurs near to but a little above the middle of a thick series of shales and rock binds, dividing the third from the fourth, or Kinderscout grit, according to the Geological Survey; or, as classed by Mr. James Spencer, of Halifax, between the third and fourth, or Pebbly grit, a group of strata which, according to Mr. Spencer's computation, has an aggregate thickness of about 450 feet.

Amongst the fossils exhibited, I would particularly draw attention to those remains of a fish, new to science, of the genus Acrolepis, and which are in a beautiful state of preservation, although in a somewhat fragmentary condition, I have, however, been able to restore, with a certain degree of completeness, the heads and a considerable portion of the bodies of two separate fishes. It will be noticed that in one specimen the head is preserved, with the exception of the extreme end of the mouth, and about one third part in length of the body, the head plates are beautifully preserved and exhibit the sculpturing upon their surfaces with marked distinctness. This specimen shows the under side of the

fish, on the right side are the remains of a pectoral fin, and on the left several small elongated plates, two of which are probably jugular plates, and on the under side are two large plates, one or both of which are opercular plates. Another specimen displays the head of a fish, smaller than the preceding, but beautifully ornamented, on the jaw on the right side of this specimen a small tooth is exposed, in shape not unlike that of a Palæoniscus, but more swollen at the base. The other specimens exhibit the central portions of the body of two distinct fishes, one exhibiting near one end of the slab a portion of a fin or tail. The scales of this fish are rhomboidal in shape, and profusely sculptured, having a number of distinct ridges and furrows, varying from seven to fourteen, according to position on the body of fish, traversing them almost parallel with their longest axis, and nearly in a line with the body of the fish, these ridges have a strong tendency to bifurcate, and not unfrequently further subdivide into two or three branches, these often again converging and becoming re-united.

ACROLEPIS is classed by Agassiz among the family *Sauroidei*, it is a ganoid fish, possessing an unequally lobed or heterocercal tail of large size, which admirably fitted it for rapid motion in following its prey, or in otherwise pursuing its predaceous habits. This genus of fish has been figured and fully described by the late Prof. Agassiz, in his "Poissons Fossiles," vol. 2, plate 52, under the name of "*Acrolepis Sedgwickii*," the specimen having been obtained from the Magnesian limestone of this country; Prof. King also gives a figure of "*Acrolepis Sedgwickii*," from the same formation, in his "Permian Fossils of England," published in the Transactions of the Palæontographical Society; and Prof. McCoy, in his "Palæozoic Fossils," plate 3 G, fig. 10, has also given a figure of the scales of this genus, under the title of "*Acrolepis Hopkinsi*," from a specimen in the Cam-

bridge Museum.* Through the kindness of Mr. Davies, of the British Museum, I have had an opportunity of carefully examining another specimen, formerly in the possession of M. de Koninck, from the Carboniferous limestone of Belgium. The scales upon which, although approaching nearer to my specimens, in the character of their ornamentation than the figures given by Prof. Agassiz or Prof. King, are yet, I feel confident, sufficiently distinct to constitute a specific difference.

It may appear strange, but so far as I could ascertain, our national collection does not contain a single specimen of this genus of fish from any of the British deposits.

It will thus be seen from this recent discovery that *Acrolepis* has a range co-extensive with the Carboniferous system, extending from the Mountain limestone through the Millstone grit and Coal measures into the Permian, in the latter of which formations it appears to have attained its maximum development, its remains having been found there more plentifully, both in our own country and on the continent, than in any of the older members of the system. In the Coal measures proper it appears to be comparatively rare.

It is not, however, my intention to make the least attempt at giving a scientific description of the specimens exhibited, my object being limited to bringing the discovery of these rare fish before the notice of the Society, to give a general idea of their appearance and characteristics, and point out the locality in which they were found with the geological position they occupied. I hope shortly to place the specimens in the hands of an investigator thoroughly competent to figure and describe them to the scientific world.

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* "It abounds in some parts of the black impure beds, intercalated between the Carboniferous limestone and overlying shale of Derbyshire." Prof. McCoy, Pal. Fos., p. 609.

In order to give a clearer and more definite idea of the exact position occupied by the shales from whence the fossils were obtained, I re-produce Mr. Spencer's section of the Millstone-grit series, in the parish of Halifax, given in the transactions of this Society, Vol. IX., part 1, page 59, commencing at the Rough-rock:—

		Feet.
No. 1 Grit.	Rough-rock	100
	Shales	300
No. 2 Grit.	Grey Grit of Rocking-stones	80
	Shales	350
No. 3 Grit.	or Galliard-rock, with coal strata	100
	Blue shales	450
	The fossils were found in these shales about 200 feet from the top.	
No. 4 Grit.	Pebbly Grit	120
	Yoredale strata	600

Only a portion of the strata, overlying the fossiliferous shale bed was passed through in sinking the shaft at the place referred to.

Description of Fossils.

No. 1. Head of *Acrolepis*—specimen exhibiting one tooth and finely sculptured head-plates.

No. 2. Head (except the snout) and part of body of *Acrolepis*—specimen showing the under side of the fish. On the right side remains of a pectoral fin; on the left, several elongated jugular plates; and on the under side two opercular plates.

No. 3. The central portion of the body of *Acrolepis*—specimen showing fin rays near one end of the slab; both sides of the fish exposed; the scales well preserved and in position.

No. 4. Central part of body of *Acrolepis*.
No. 5. Portion of fin rays of *Acrolepis*.
No. 6. Portion of *Acrolepis*, exhibiting very distinctly the mode of attachment and interlocking of the scales.
No. 7. Spine of *Rhizodus Hibberti ?*
No. 8. Lower portion of the tooth of *Ctenacanthus hyboides ?*
No. 9. Part of the body of *Acanthodes*.
No. 10. Detached scales of *Acanthodes*.
No. 11. *Palæoniscus*. Detached scales.
No. 12. Teeth of *Cladodus*.
No. 13. *Goniatites*—very thin and discoidal. All from the lower portion of the millstone grit shales, Wadsworth Moor.
No. 14. Tooth of *Stropsodus*.
No. 15. Tooth of *Cladodus*.
No. 16. *Spirifer pinguis*.
No. 17. *Corallines*.
No. 18. *Encrinital ossicula*.
No. 19. *Annelid* burrows. From a bed of grey limestone, millstone grit, North Clapham, Yorkshire.

On the motion of Mr. J. Knowles, seconded by Mr. W. Boyd Dawkins, the thanks of the Society were voted to Mr. Aitken for his valuable paper.

Mr. Boyd Dawkins said: I am very glad that such an admirable discovery has been brought before us. It seems to me very important to have extended the range of the genus *Acrolepis* so low down in the British carboniferous rocks. So far as I know, to the time of this discovery, it had not been found so low as this horizon. There is one point about which I would like to ask Mr.

Aitken a question: that regarding the *Ctenacanthus*, the specimen exhibited is so like *Cladodus* that I should be inclined to put it down to that genus.

Mr. AITKEN: It is a rather doubtful definition, and I adopted it with some hesitation. The name for this specimen was given me by Mr. James Thompson, and I relied on his judgment rather than my own.

The CHAIRMAN: There is no reason why this fossil fish should not be extended low in the millstone grit series—even to the bottom of it. As far as my observation extends, the whole millstone grit, quite independently of these fossil remains—is undoubtedly conformable both with the carboniferous limestone below and with the coal measures above. The finding of fossil shells like the *Nautilus*, *Goniatites* and *Discites* is to some extent new, so low down in the series, hitherto the horizon for these shells has been near the upper foot coal, which overlies the gannister coal; and for many years it was supposed that they did not occur higher in the series than the mine which lies some forty yards above the last-named coal. When the geological survey was going on in this part of the country, Professor Hull and Mr. G. H. Green, in 1861, discovered some of these fossils higher up in the series—in the upper part of the middle coal measures which overlie the great and Roger mines at Ashton-under-Lyne—showing such a wide range that they may yet be found throughout the whole series of the coal measures to the mountain limestone. Mr. Aitken has found a thin bed of mountain limestone, if he could penetrate a little deeper I have no doubt he would find more limestone. There is not a complete section of these strata down to the limestone in the Hebden Bridge valley; but if we make an examination, say between Bury and Sabden over to Chatburn, we find, as we get deeper

into the Yoredale series, thin bands of limestone first begin to appear, then occasionally they get to be about a foot in thickness. I think what Mr. Aitken has described is quite in accordance with what we would have expected, and it is pleasing to find that these fossil remains from the millstone series confirm all the views that we had previously entertertained upon the subject.

Mr. PLANT: It is rather remarkable that the late Mr. Gibson, the geologist, of Hebden Bridge, who was credited in his day to have exhausted any chance of further finds in the fossiliferous Yoredale shales, should have failed in discovering any fishes in the shales in that district. Mr. Gibson was a man of remarkably keen perception in hunting after fossils, but no *Acrolepis* was ever brought to light by his labours. It is a very happy discovery for Mr. Aitken that he should have found such a rich fossiliferous band in the Kinderscout grits, which have hitherto been regarded as barren over the high moors of Lancashire and Yorkshire, and it gives us better hopes of making Lancashire more interesting in the fossils of its extensive series of carboniferous rocks. I believe these fishes, *Acrolepis*, have been found in the lower coal measures at Newcastle-on-Tyne by Mr. Barkas, who has figured the teeth and jaws. It will be a very fortunate thing for Mr. Aitken if he can continue his researches at Hebden Bridge for some time longer, and obtain other specimens of its treasures. I do not think very much of the fossils from the limestone band low down in the Millstone grit, although the occurrence of a limestone band in Millstone grit is in itself of considerable interest, the fossils are ordinary species, well known in the Yoredale shales. With regard to Mr. Dawkins's remark, I wish to say that I have a disbelief in

the recognition of specific characters of fishes of the coal measures from their teeth alone. I have now a collection of between one and two thousand teeth, and the closer I examine the variety of forms and markings upon teeth so grouped together as to lead to the belief that they belonged to one jaw, the more cautious I become in regarding as of any value species, differentiated from isolated specimens of teeth.

Mr. WILD: This is a very fortunate discovery, but the *Acrolepis* has been found before in the Arley mine at Burnley. I exhibited a very fine specimen when the British Association met in Manchester; it was new, but it was decided to be *Acrolepis*, by the best authorities.

The CHAIRMAN: That was the last discovery of a fossil of this genus which you know of in the Arley mine at Burnley, which corresponds, I suppose, with the Arley mine at Wigan? But Mr. Aitken's discoveries go very much lower —many hundred yards lower—in the series than that.

Mr. WILD—It is a surprise to me that Mr. Aitken should have discovered them there. It has, as Mr. Plant says, been considered barren ground, because the late Mr. Gibson, of Hebden Bridge, never met with fish scales there. It may be that, taking a much greater interest in fossil shells, he did not recognise fish scales, even of *Palæoniscus*, which has been found there in later years.

Mr. AITKEN: The scales of *Acrolepis* are distinct from *Palæoniscus* in size, structure, and appearance. I must observe that the reason Samuel Gibson never found these remains was, no doubt, because these specimens were found 800 or 1,000 feet above the valley where he used to work. He worked in the Yoredale series in the bottom valley; these were found on the top of Wadsworth moor, at a considerable

elevation, they would not have been brought to light now but for a tunnel being driven through Wadsworth moor, from which the fossils were excavated, so far as I know, they have never been found anywhere in the district except at this point and under these circumstances. With regard to the variety of teeth that Mr. Plant has alluded to as occurring in the mouth of some fishes, I quite agree with him. Doubtless a great variety of forms do exist in the same individual, but with regard to the *Diplodus*, it is doubtful whether it is a tooth or a dermal scute, more than one palæontologist holds the opinion that it is not a tooth. This newly-discovered fish, as far as I know, is not figured. I believe it to be an entirely new species of *Acrolepis*. At the British Museum, I had an opportunity of examining and comparing this specimen with their specimens of *Acrolepis*. One from the mountain limestone of Belgium approaches it most nearly in sculpture and character, but this is, as I have stated, in my opinion sufficiently distinct to make it out to be a new species.

The reading of a paper on PEAT FUELS, by Mr. J. Plant, was, with the consent of the meeting, postponed until the next Ordinary Meeting.

PROJECTED CHART OF ERRATIC BLOCKS OF ENGLAND AND WALES.

Mr. BOYD DAWKINS said: I wish to lay before the Society a resolution which was passed by the British Association at the Bradford Meeting in 1873, and which has been formulated for distribution throughout the country in the following circular:—

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Boulder Committee.

Dear Sir,

At the last meeting of the Association the following resolution was passed:—

"That Professor Harkness, Mr. Prestwich, Professor Hughes, "Rev. H. W. Crosskey, Messrs. C. J. Woodward, W. Boyd Dawkins, "George Maw, L. C. Miall, G. H. Morton, and J. E. Lee be a "Committee for the purpose of recording the position, height above "the sea, lithological characters, size, and origin of the more impor- "tant of the Erratic Blocks of England and Wales, reporting other "matters of interest connected with the same, and taking measures "for their preservation; that the Rev. H. W. Crosskey be the "Secretary, and that the sum of £10 be placed at their disposal for "the purpose."

On behalf of this Committee, I beg respectfully to request your kind assistance in making the investigations entrusted to them; and forward a printed form on which the information desired may be recorded. I shall be greatly obliged by the receipt of any communication with which you may be able to favour the Committee at as early a date as possible.

Very respectfully,

Henry W. Crosskey,
Secretary.

28, George-road, Birmingham,
, 1874.

The Association has appointed this Committee for marking down on a map the position of the large boulders in this country, so that the exact track of the ancient glaciers may be ascertained in the same way as is being done in Switzerland and the south of France. In order to do that, the Committee have circulated forms containing a number of questions, and they would be glad if gentlemen interested in the matter would supply information with reference to the boulders in this neighbourhood. The filling up of such forms is of the utmost value. When I was at the Associa-

tion for the Promotion of Science, at Lyons, last autumn, I saw a magnificent map, showing the track of glaciers from the Alps, for 300 miles, into France. They were traced as truly as if anyone had seen them, carrying down gravel and boulders, on their way. It was by circulating queries like these that they were able to construct such a map.

The CHAIRMAN: Members of the Society who do not believe in the glacial theory need not be afraid to furnish the information asked for, because the Committee do not put it as though the boulders had been transferred by glaciers, but "by some natural agency" more or less remote. So, whatever the agency, the notes will show in what direction the drift has gone.

Mr. PLANT said it was of great importance that accurate information on this subject should be obtained. There was in the public park at Macclesfield the largest glacial boulder in the North-Western Counties. It was said to weigh 30 tons. The inscription wrongly described it as being "a block of Ravenglass granite." It was, however, a piece of amygdaloid trap, as different as possible from granite. The forms issued by the Boulder Committee showed that their attention was directed to the great value of a true recognition of the petrological characters of each of the boulders, so that if possible they might all be traced back to the parent rock in situ.

The following are the questions to which the Committee require answers, and members of the Society residing in the country may have their attention drawn to any local boulders, and probably be able to supply important information respecting them to the Committee of the British Association:—

British Association for the Advancement of Science.

BOULDER COMMITTEE.

If there are in your District any (A) ISOLATED ERRATIC BLOCKS *or* BOULDERS, *or* (B) GROUPS OF BOULDERS—i.e., *Masses of Rock, evidently transported by natural agency from some locality more or less remote—please return this paper, with answers to the following Queries, to the* REV. H. W. CROSSKEY, *Secretary to the Boulder Committee*, 28, *George Road, Birmingham.*

(A) ISOLATED BOULDERS.

1. What is the name of the Parish, Estate, and Farm on which Boulder is situated, adding nearest Town, and County and any particular enabling its position to be marked on the Ordnance Map?
2. What are the dimensions of Boulder, in length, breadth, and height, above ground?
3. Is the Boulder rounded, subangular, or angular?
4. If the Boulder is long shaped, and has not been moved by man, what is direction by compass of its longest axis?
5. If there are any natural ruts, groovings, or striations on Boulder, state—
   (*a*) Their lengths, depth, and number.
   (*b*) The part of Boulder striated, viz., whether top or sides.
   (*c*) Whether the striations are in the direction of the longer axis, or at what angle to it?
6. What is the nature of the rock composing the Boulder? If it is of a species of rock differing from any rocks adjoining it, state locality where, from personal observation, you know that a rock of the same nature as the Boulder occurs, the distance of that locality, and its bearings by compass from the Boulder.
7. If Boulder is known by any popular name, or has any legend connected with it, mention it.
8. What is the height of Boulder above the sea?
9. Is the Boulder indicated on any map, or does it make any boundary of a County, Parish, or Estate?
10. If there is any Photograph or Sketch of the Boulder, please to say how Committee can obtain it?
11. Is the Boulder connected with any long ridges of gravel or sand, or is it isolated?
12. Upon what does the Boulder rest?

(B) GROUPS OF BOULDERS.

Though there may be no one Boulder in your district so remarkable as to deserve description, there may be Groups of Boulders.

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1. What is the name of the Parish, Estate, and Farm on which they are situated, adding the nearest Town, and County, and any particular enabling their position to be marked on the Ordnance map?
2. What are the dimensions of the smallest and largest Boulders of the group?
3. Are the Boulders rounded, subangular, or angular?
4. If any large Boulder of the group (which has not been moved by man) is long shaped, what is direction by compass of its longest axis?
5. If there are any natural ruts, groovings, or striations on any Boulder, state—
   (*a*) Their lengths, depth, and number,
   (*b*) The parts of the Boulder striated, viz., whether top or sides.
   (*c*) Whether the striations are in the direction of the longer axis, or at what angle to it?
6. State (*a*) localities where rocks undoubtedly of the same nature as Boulders occur.
   [*Be careful to ascertain that none of the Boulders have been brought from a distance by human agency.*]
   (*b*) The distances of those localities and their bearings by compass from the Boulders?
7. What is the nature of the Rocks composing the Boulders; and in what proportions do the Boulders of the various rocks represented in the group occur?
8. What is the height of the group above the sea?
9. Over what area does the group extend, and what number of Boulders are there in the group or per acre?
10. Are the Boulders exposed on the surface, or are they surrounded by any deposit? Add any observations explanatory of the position in which the Boulders are found.

At the ORDINARY MEETING of the members, held at the House of the Literary and Philosophical Society, on Tuesday, 24th February, 1874.

JOHN KNOWLES, Vice-President, in the Chair.

The following donations were announced :—

From Dr. F. V. Hayden, U.S., Geologist, Washington, D.C.

"Contributions to the Extinct Vertebrate Fauna of the Western Territories," 4to.

Vol. I., "Fossil Vertebrates," by Prof. Joseph Leidy.

Vol. V., Part I., "Acrididæ of North America," by Cyrus Thomas, Ph.D.

"Profiles, Sections, and Illustrations to the final Report of the Chief Geologist of the Survey of the Territories," 4to, 1872.

"Sixth Annual Report of the U.S. Geological Survey of Montano, Idaho, Wyoming, and Utah in 1872, 8vo, 1873."

From E. T. Cox, State Geologist, Indianopolis, Indiana.

"Third and Fourth Annual Reports of the Geological Survey of Indiana in 1871-2," 8vo.

"Case of Maps to the above."

From Verplanck Colvin.

"Report on the Topographical Survey of the Adirondack Wilderness of New York," 8vo, 1873.

From the Board of Regents.

"Annual Report of the Smithsonian Institution for the Year 1871," 8vo.

"Archives of Science of the Orleans County Society, Vermont, U.S." Nos. 4, 5, 8vo., 1871-2.

Mr. J. PLANT, on behalf of Mr. Spencer, exhibited several portions of fossil bones of the mammoth, *Elephas primigenius*, which had been taken from the *debris* of a cavern recently discovered in the limestone quarries belonging to Mr. E. G. Spencer, of The Willows, Crosshills, near Skipton. The specimens were in a fragmentary state, the limestone *debris* having to be broken up, and the bones were very tender and wet; the largest was a portion of tusk about eight inches long, the next was about five of the transverse plates of an upper molar, the others being fragments of tusk. Many others were obtained at the same time. The cavern has had to be made inaccessible on account of the workings in the quarry, when it is reopened great care will be taken by Mr. Spencer to extricate the remaining bones as perfect as is possible. The site of these extensive quarries is midway between Foulridge and Kildwick Stations, about a mile from the border of Lancashire. The limestone is a lower stratum than that worked four miles north at Skipton.

Mr. AITKEN moved a vote of thanks to Mr. Spencer for his communication, which he said was important. He trusted that at the reopening of the cavern some members of the Society might visit it and take careful observations of the points of scientific interest belonging to it, for it was likely to present some important feature if seen in an undisturbed state.

Mr. LIVESEY seconded the motion, which was passed.

Mr. PLANT read a paper on the Peat Fuels and other manufactured fuels exhibited in the Peel Park Exhibition.

PEAT FUELS AND THEIR ECONOMIC VALUE.

By. Mr. J. Plant, F.G.S.

The formation of peat may be looked upon as one of the most striking physical features of the geological changes at present in progress. There exist abundant proofs that in most cases turfs, mosses, bogs, peats, turbaries, and morasses—as they are locally called—occupy ground upon which vast forests of oak, pine, elm, ash, birch, willow, and other trees were growing at a comparatively recent period, probably not more remote than the age of the oldest stone weapons (the palæolithic), in all cases certainly of more modern date than the alluvial deposits of drift of the later quarternary age. Their situation is in no way peculiar, as they are found alike spread over the plain, the high moor, and the summit of the mountain, resting on glacial clays,* gravels, littoral, and alluvial sands, and even directly upon the bare rocks. Peats and mosses thrive better and grow with greater rapidity on low rather than on high ground, and owing to this fact the bogs which are situated upon mountain tops and slopes rarely exceed six feet in depth; whereas the bogs of the plains and lowlands are found to attain a depth of from 50 feet to 80 feet.

The surface covered by peat beds in England is considerable and widely scattered, except in the Midland Counties. It is much greater in Scotland, but most extensively seen in Ireland. Mr. O'Hara (*Dublin Quarterly Journal of Science*, vol. 4, p. 261) estimates the peat bogs of Ireland at 1,576,000 acres occupying the limestone plains, and 1,255,000 acres on the hills and mountains, showing a total of 2,831,000 acres of turf and bog. If we take as an approximating fair estimate of the peat bogs in Great Britain 3,500,000 acres,

* Principal Dawson ("Arcadian Geology," p. 68) says at Cape Breton the peat lies below a bed of boulder clay.

we find a total extent of peat in the British Isles equal to in round numbers 6,000,000 acres; and if we accept an average thickness of 12 feet deep over this enormous area, and each acre as capable of supplying 12,000 tons of peat fuel, we may justly regard this as a powerful auxiliary to keep up the steam-producing power of Great Britain, and to some extent help to stave off the day of the exhaustion of its coalfields.

On the Continent, especially in the north, extensive tracts of country are covered with beds of peat, and even in the southern parts of Europe peat beds of great size and depth are found, stretching along the shores and right into the sea, from the subsidence of the land. In the United States of North America, in Orleans County, Vermont, the peat deposits are more than 100 feet deep of preglacial age; in Canada, and the colder parts of the world generally, peat beds and morasses occupy vast tracts of country, but in the tropical zones the decay of vegetable fibre after life has ceased is too rapid to permit of the formation of peat.

Peat is simply vegetable matter partially or wholly decomposed, and in no sense of scientific technology can it be regarded as a mineral, like lignite or coal. Numerous species of marsh plants have helped in its formation, but the bulk of peat in northern latitudes is formed by a species of sphagnum (*sphagnum palustre*), or bog moss. These mosses delight in exposed and wet situations, and each year throw out new shoots at their upper parts, whilst the lower parts are decaying and being converted into peat. Layers of trees are not unfrequently found in beds of peat, showing the fact that forests grew on the site, and probably by their fall obstructed the drainage, and thus primarily caused the mosses to grow, and the peat to form.

The growth of peat varies greatly, in some places a bog has been known to increase two inches in depth in a year,

but the greater number of peat beds are of slow growth. Where water is abundant the whole of the peat may become a floating mass of long interlaced ligneous fibres of plants resting upon a soft yielding deposit of humus; and after heavy rain the whole mass may burst over its boundaries and overwhelm the fertile lands lying below, as is on record so often the case in Ireland.

Although bogs and mosses are mainly alike in their general characters, yet there are differences between them, and much difference between the peat cut at different depths of the same bed. Near the surface, and frequently for a depth of about five feet, the ligneous fibre is perfectly discernible, and from thence downward to a variable depth the vegetable fibres may be traced through various stages of decay, until at the bottom of the deposit all traces of vegetable fibre are lost in the complete decomposition which has been brought about by time and chemical change. The denser portion, which forms the lower stratum of a bog, is the most valuable; it is easy to work, and when dried it abounds in inflammable materials, it makes the best fuel, and burns like a bituminous coal. The peat of the high moors and mountains is generally more impure than the peat of the plains, owing to the amount of disintegrated rock which, from atmospheric influences, gets disseminated through the peat; then it is harder and tougher in fibre, owing to its slow and stunted growth; all of which lessen its value as a fuel.

The chemical nature of the change by which peat has been produced from mosses is probably very similar to that by which bituminous minerals have been formed from analogous materials. It consists chiefly in elimination of oxygen and hydrogen in the proportion to form water, also of oxygen and carbon to form carbonic acid, and of hydrogen and carbon in the proportion to form marsh gas and other hydrocarbons,

the main feature of this change being the increase in the amount of carbon in the residual substance—the varieties in peat depends upon the extent to which this change has advanced, peat when slightly altered approximating to the texture of ligneous tissue or wood—and with greater alteration approximating to that of lignite, coal, or other bituminous minerals, both in physical characters and in composition; probably if deposits of peat were placed under conditions such as those in which coal has been produced, peat might in process of time become converted into coal.

When the land was covered with forests, wood was the cheapest fuel, but as in the course of time it became scarce, peat and coal were the substitutes, coal was preferred as it was cheap, compact, and at once ready for use; but in countries where coal is scarce peat has long been the only available fuel for domestic and general consumption, and is used most extensively in blasts, forges, smelting ores, and for locomotives. In Holland the making of peat fuel is a great and lucrative industry; above 40,000,000 tons of hard peat fuel are made annually, and £140,000 is paid to the Dutch Government as excise duty every year.

In that country peat is divided into four classes, viz.:—"Long Turf," a dry, light, and very fibrous material obtained from the high fens, which is cut into long slabs and air dried—this sells for prices varying from thirteen to nineteen shillings the English ton; "Short Turf," obtained by dredging the water-covered turbaries, it is well kneaded by treading it under the wooden sabots of the workmen, cut into short bricks, air dried, and sold to the hotels and upper classes from fourteen to nineteen shillings the ton; "Derrie Turf," obtained from the coasts lying under the sand dunes—about the same value as the preceding; and, lastly, "Rahder Turf," a machine-manufactured peat fuel, produced by a process similar to that described in the Clayton process.

The cost of making Rahder peat fuel is six shillings and sixpence the ton, it pays a heavy excise duty and sells for about ten shillings per ton at the works, and nineteen shillings the ton at Delft, about 100 miles from the works.

Whether peat fuel is applicable to the same purposes in England as coal and wood is a question that never has had a chance of being practically tested, in consequence of the enormous and cheap supplies of coal; but with the present great advance in its price, and with a prospect of its maintaining a high price in the future, it may be possible that those interested may yet be compelled to turn their attention to the greater economy in using peat fuel, and they may then discover that its excellent merits, which have long been known and passed beyond all question with the great users of fuel on the Continent, are not to be despised.

The most serious obstacle to the useful application of this fuel upon an extensive scale arises from the large amount of water held in the peat in its natural state, and in the practical difficulties of effectually separating this water by any quick heat drying processes. The hydroscopic water retained in all air-dried peats is also prejudicial to its utility, for when the water is separated by drying the peat in thin bricks, there still remains from 15 to 30 per cent. of moisture in the air-dried peat fuel, when air-dried peat is exposed to a temperature of boiling water, it generally loses from 15 to 30 per cent. of its weight, chiefly consisting of hydroscopic water, and volatile products; at higher temperatures peat is entirely decomposed and utterly ruined in all its qualities as a peat fuel.

Every scheme by which the peat is subjected to high pressure, or in which direct heat or heated air is used, in order to rid the peat of its superabundant wetness, has failed to produce a peat fuel of any commercial value, and most of such schemes have resulted in proving that it was next to

impossible by such means to manufacture an economical peat fuel. There exist already above one hundred patents for the making and converting raw peat into fuel for steam and domestic uses, and of these not more than half a dozen ever attempted to work upon a scale so large as to prove their practicability.

The favourite methods with inventors of treating the crude peat have been compression by hydraulic power, separation of the vegetable fibre from the matrix, maceration, grinding, and rapid drying by heated air. These modes of dealing with the peat are all liable to failure from various causes. Generally peat will yield an average of 70 per cent. of water, and any process that aims to get rid of the water in a rapid manner has been found not to answer. The application of a high degree of heat seems to overbake the peat and rob it of a large amount of its calorific value. The attempt to abstract the ligneous fibre from the humus of the peat was a costly experiment to deprive the peat of its most substantial and valuable material for the purposes of fuel.

The following is a description of the peat fuels and processes of manufacture in the Exhibition:—The exhibits of *Messrs. Clayton, Son, and Howlett*, are the most extensive and complete. It includes a full-sized machine for preparing peat for fuel, a model of the drying shed, and drawings of machines for making lignite fuel, charcoal, and compressing machinery for forming waste and slack into blocks of coal, specimens of peat fuels and products made from peat by the Clayton process are also exhibited from the following places: Highland peat fuel, South Morar (west coast Inverness-shire, a field of 900 acres of peat, calculated to supply 2,625,000 tons of peat fuel); South of Scotland peat, Kirkconnel Moss; Ulster peat fuel, Clenravel, township of Cargan; London Lead Company, Middleton-in-Teesdale; Dunlewey peat

(county Donegal); Dublin peat fuel, Huddersfield, Holstein lignite, and Fenns Bank Moss, near Whitchurch.

One of Messrs. Clayton's machines when in fair working order will in ten hours manipulate 120 tons of crude peat, which, after the mastication and loss of its free water, will yield about 25 tons of solid peat fuel. The specific gravity of the peat fuel, when ready for use, is only about 6 per cent. less than that of ordinary coal, this method of converting the crude useless peat into a useful fuel differs materially from all the methods which have before been attempted.

The process of working peat into fuel is as follows:—The crude peat is dug out and placed in trucks to the weight of about half a ton, the trucks run upon rails to the works, and are drawn up to the platform of the machine by a horizontal windlass worked by a belt from the engine. The crude peat is pitched into a hopper, and falls into a chamber in which a shaft, carrying a set of screw-like blades, revolves, cutting up the peat into very fine portions, and liberating a good deal of its moisture, at the same time kneeding it over and over. In mosses where there exists stony peats that would endanger the blades and screws in the machine, an arrangement for screening the peat at this point is introduced, and the stones are separated from the fibre and peat.

The cylinder which forms the bed of the machine has a central shaft revolving, upon which are fixed propelling screws, whilst a series of steel discs are so arranged upon it that they form a dissected double screw running in the whole length of the shaft. Along the bottom of the cylinder is fixed a row of cutting blades of hardened steel, between which the discs work as they revolve, by the joint action of the blades and screws the peat is forced along, and is carried within the reach of the discs, and at each revolution

the peat is brought against the cutters by the forward action of the discs. The peat is effectually "masticated" by these means, and in a short time the fibre of the peat is minced and reduced to a pulp and brought into a homogeneous state at the delivery end of the cylinder, from which it emerges through five openings in continuous rolls of the consistency of butter, these rolls are received on a number of rollers, over which the peat travels on to a lathed tray of a portable size.

A boy cuts off the lengths of peat which are on the tray from the exuding mass, and sends the tray with its long rolls of peat down an inclined guideway, and at a convenient point upon the guideway the rolls of peat are brought under the wire-cutting frame, and at one stroke are cut into thirty-five briquettes. The tray is then carried to the drying shed and left for three or four days, according to the state of the weather. The briqnettes soon acquire sufficient firmness to bear handling, and are then removed from the trays and stacked in open racks of special construction, where they remain to complete the drying process. The size of these briquettes when first cut upon the tray is 7 × 4 × 3 inches, and after the process of drying and induration is completed they are reduced to $3\frac{1}{4} \times 1\frac{3}{4}$ inches, which, when converted into charcoal briquettes, only measure $1\frac{1}{4} \times 1$ inches.

The rationale of this method is, simply to cut the peat into fragments in its raw and wet state, drain off as much of the water as will freely run away; then masticate the fibres and whole mass of the peat together in the machine until it becomes difficult to distinguish any ligneous fibre distinct from the humus in which it is so entirely mixed. By these means the fibre and root, which really form the bulk of all peats, are preserved, and yet the peat is largely deprived of its power to absorb or hold water, and when placed under cover to dry in the sheds it soon gets solid and very compact

in structure. Many practical experiments have been made in locomotives, smelting works, gasworks, foundries, and manufactories, in which the exact value and economic use of this peat fuel has been tested; and it would appear that condensed peat fuel is for many industrial purposes actually preferable to coal. In particular, it is found to be better suited for iron smelting, owing to the entire absence of either sulphur or phosphorus, and in the furnaces of steamers and locomotives on account of its superior heat-generating power.

If we are to put to the test the economic value of these peat fuels, and are ready to grant their practicability where there is an abundance of the crude peat, as in many parts of Lancashire, the question arises as to the cost of its production and price in the market, calculations have been made having regard to the high price of labour and materials in the present day, and it is stated that for £1,700 a complete establishment—engine, machine, trucks, railway, drying sheds—could be placed in working order on any of the Lancashire mosses, making an average of 150 tons of peat fuel weekly.

Danchell's Peat Fuel and Peat Filters for Sewage, Red Moss, Horwich, Lancashire: The samples of manufactured peat fuel made from the light brown moss differ from other specimens of peat fuel in respect that the humus and ligneous fibre of the peat are macerated and reduced to a state of a fine chocolate paste. The machine consists of a long cylinder, in which works a shaft armed with proper cutters and discs, by which the crude peat is soon reduced to the consistency of pasty pulp and issues in a long roll, of any shape or diameter; this is cut into briquettes by a wired frame, and the briquettes are dried in the usual way under a covered shed; in drying they lose one-half of their bulk, and in a fortnight are converted into a good hard fine-grained fuel, and when roasted into charcoal are about one-third their original size.

The charcoal is of excellent quality. In addition to the peat fuel and charcoal, a third variety of fuel is manufactured into briquettes by mixing with the peat about one-eighth part of fine coal slack, which produces a good flame and gives off a larger amount of heat than the peat fuel. The producers of the Dunchell peat fuel also convert the peat into sewage filters by incorporating the peat with a mixture of clay and charring them, experiments are now being carried out in the town of Bradford, in Yorkshire, and in Paris, with these filters, which are claimed to be very efficacious in purifying the liquid sewage of large towns. "Each ton of charcoal is equal to the absorption of at least two tons of solid sewage matter."

Peat Fuels from Sutherland (Mr. John Pender, M.P.): The four varieties of fuel sent from the extensive works of the Duke of Sutherland are in the shape of machine-pressed bricks, 9 × 6 × 3 inches in size. A common element is prevalent in each variety—shale tar. The peat fuel appears to be prepared from charred peat, which has been broken by a machine so as to leave it in a rough granular state, and afterwards well worked up with crude shale tar and pressed into bricks by a moulding machine. The quantity of shale tar taken up by the vegetable peat has been considerable, and gives it a thoroughly carbonised appearance. This gives it in burning a roaring flame and swift consumption in the draught of a steam furnace; the second sample is of coal slack and shale tar pressed into bricks in the moulding machine; a third sample is composed of peat, coal slack, and shale tar; a fourth of steam coal (*anthracite*) and shale tar.

Peat Fuel and Charcoal (Peat Coal and Charcoal Company): The samples of this exhibit are remarkable in showing what a degree of density it is possible to effect in ordinary peat by manipulation and perfect drying. Some

of the samples are close grained and hard, and look like mahogany wood. They are carved into ornaments and polished. Their value as fuel and their cost are not stated. The charcoal made from this peat is remarkably good; and the fuel made from coal dust and peat is of a crisp and quick-burning character.

Peat Charcoal, or Carbonised Peat (Mr. Joshua Kidd): There are many ways in use, or which have been proposed, for the profitable conversion of peat into charcoal by a direct and simple operation. The one shown in the samples made by this process would appear to have realised a considerable amount of success in obtaining an article with excellent qualities as a fuel, and as a deodorising agent and filtering medium for foul water and sewage. In France this peat charcoal has been largely used in making gunpowder, under the name of *charbon roux*, and experiments for its production have been extensively made on the estates of the Duke of Sutherland, where 30 tons of charred peat, costing £11 10s. 9d. were turned out weekly. It burns with great heat and with but little smoke, leaving a yellowish white ash which forms an excellent manure.

The model of the machine, which is applicable to carbonizing peat, wood, coal, &c., shows an oven-like chamber 25 feet by 10 feet, 3 feet high, into which the dried peat is carried on convenient carriages, having gratings to hold the briquettes of peat. The chamber being filled, it is closed with iron doors so as to exclude the admission of free oxygen, the furnace attached is then lighted, the ordinary draft through the flue being employed to raise the heat. The heat in the chamber soon rises to between 300° and 400°, and an artificial draught is created by jets of superheated steam, forcing the heated gases and the products of combustion through the uptake into the chamber, which, as they contain no free oxygen, make it impossible for the

charring peat in the chamber to take fire. The fuel used in the furnace is peat, and it supplies the gases forced into the closed chamber. These heated gases are allowed to escape through openings at the base of the first chamber, and are then utilized by passing them into a second chamber filled with briquettes of peat. By means of these contrivances, peat is carbonized at the lowest possible temperature, which to a great extent acts in retaining the volatile matters, and leaves the peat very rich in hydrocarbons, peat thus prepared produces a gas of illuminating power of about 22 candles, and from 6,000 to 9,000 cubic feet per ton, leaving 33 gallons of a tarry oil, and 42½ gallons of water containing acetic acid. The charcoal which remains after the gas is taken off contains only a trace of sulphur and no phosphorus, and is valuable for smelting purposes. It is estimated that a ton of peat charcoal can be produced by this method at a cost of 13s. 6d., and the peat fuel is of considerable commercial value.

Eichorne Process for Condensing Peat—Ball Peat—(Mr. A. Pelly): In this machine the crude peat is reduced to a state of pulp. It is carried through a hopper into a horizontal cylinder having a shaft armed with a number of arms like an Archimedian screw, rotating very rapidly, by which the fibre is most effectually broken and a large amount of moisture released. The pasty pulp is forced through a circular opening, and is cut into suitable lengths by a rotatory knife, these lengths fall into a truncated cylinder, and in revolving are made to assume a rough spherical form, and are then conveyed into the drying shed. The specimens of peat balls are hard, clean, and of convenient size; burn with a bright flame, and give an excellent heat, even getting up steam rapidly, and making but a small amount of smoke, sulphur, or ash. Their calorific value when compared with coal is—coal, 1·00; ball peat, 1·37. This process of peat

compressing is largely carried on in Germany and Sweden. It can be sold at 6s. per ton, and a ton and a half is equal to the work of a ton of coal.

Peat Fuel (Mr. Robert Kerr Aitchison): This peat is broken up in a machine, by means of which it parts with a great deal of its water. It is then manipulated in a masticator, and finally, broken asphalt is mixed in the mass, it is then shaped into briquettes and dried under sheds. Its specific weight is less than most other made peats; the addition of asphalt adds to its cost, but gives it a greater value for steam and furnaces.

Condensed Peat (Mr. C. E. Bambridge): The peat is pulped and shaped into long briquettes, which, when dry, make a compact and hard fuel, of excellent calorific quality. The charcoal made from this fuel is pure and valuable.

Hand-manufactured Peat Fuel (Carrington Moss Peat Fuel Company): This peat is the only one which exhibits a fuel made from crude peat by hand process alone. The samples are in the form of small bricks of umber colour, and retain a larger per centage of moisture than do the machine peats. It burns with a poor flame, and its calorific quality is not very high, from its want of a more compact density.

Buckland's Patent Peat Fuel: One of the methods of making a peat fuel of excellent quality was followed for a time in County Leitrim, Ireland, by Mr. Buckland's patent, 1861. The peat was very finely treated in a machine having a strainer for the fibre, and the moisture was evaporated by a high heat. The process is as follows:—When the peat is dug from the bog it is thrown into a hopper, beneath which is a strainer formed of perforated metal; and within the strainer is an archimedian screw; at the bottom of the strainer is a small opening through which any very coarse

undecomposed roots and fibres, which will not pass through the perforations of the strainer, fall into a waste pipe and are rejected, or may be used for any purpose not requiring superior fuel. By turning the screw within the strainer the small fibres are cut up by the sharp edges of the perforated metal, through which they pass with the decomposed part of the peat, with which they thus become assimilated. A strainer of two feet in diameter, with perforations of one-eighth of an inch diameter, and fifteen to the square inch, contains about 12,000 holes, which are equal to an aggregate aperture of a square foot; a strainer of this size will discharge about eight tons of peat per hour, or nearly 100 tons in twelve hours. The decomposed peat protrudes through every hole in the strainer, and drops, in vermicular forms, upon an endless band which delivers the strained peat into a brick machine, which will mould it in any suitable shape or size that may be preferred. The strainer being enclosed in a heated chamber, with an opening for the escape of steam, the moisture is rapidly driven off from the worm-like strings as they fall upon the band, giving solidity to the moulded blocks of peat as they pass through the die of the brick machine; and their being then at a high temperature, expedites the subsequent process of drying. Very little power is required for the whole operation, which is performed continuously and with great rapidity. The moulded blocks of peat are removed to a drying shed, through which a current of hot, moist air passes; and they soon, without compression, become as hard as oak, and more dense than any peat submitted to hydraulic pressure, the specific gravity being from 1·15 to 1·50, and that of highly compressed peat 1·08. From four to five tons of wet peat, as taken from the bog, are required to make one ton of dry condensed peat, the total cost of which is about 3s. 6d. per ton. Peat thus prepared burns very freely, will stand a powerful

blast, emits great heat, is smokeless, and produces less ash than the average of coal or coke. It is impervious to water, improves by keeping, and is incapable of self-ignition. From two and a half to three tons of prepared peat will make one ton of excellent charcoal, the cost of which would be about 12s. per ton; but in converting the peat into charcoal one cwt. of hydrocarbon or peat tar may be drawn from one ton of peat, the value of which for illuminating and lubricating purposes will greatly reduce, if not entirely cover the cost of the charcoal. The peat fuel prepared in this way was experimentally tested in smelting iron ore; the pig iron was decided to be seven per cent. below the best standard and twenty-nine above the worst kind of pig iron. The process, however, was found to be impracticable from the reasons already stated about heat-dried peats.

In addition to these samples of the peat fuels and illustrations of the different processes by which they are manufactured, the Exhibition contains drawings of other machines for the treatment of peat, viz.—Mr. J. J. Hayes has drawings of a centrifugal machine for partially extracting the water from crude peat and stamping it into blocks; and Mr. J. G. Bass, drawings of peat manufacturing machinery. Mr. Simpson exhibits a conical peat manufacturing machine, which claims to possess advantages of compactness, and in being a portable hand-worked machine, capable of producing the largest amount of condensed peat with the least expenditure of manual labour. In experiments made at the Exhibition, this machine turned out an excellent material from a fibrous peat from Carrington Moss, and appeared to be well adapted for any farm near a moss. One labourer could readily make fuel enough in one day for a week's consumption. Messrs. Carter show a disintegrator for grinding peat or other material.

In a sample of dried peat from Scotland, analysed by *Mr. James Dewar*, F.R.S.E., F.C.S., he gives—volatile matter, 64·2; charcoal, 33·7; ash, 2·1 = 100·0. The calorific value of this peat is expressed by saying—one pound when burnt would raise 4,500 lbs. of water 1¾° Fahrenheit, *i.e.*, one part by weight of the peat would raise 45 lbs. by weight of water from the freezing to the boiling point.

The quality of the peat was excellent, well disintegrated in the fibre, and free from earthy impurity.

An analysis by Professor *A. Vassard* of a sample of Cambridgeshire Peat Fuel, gave—moisture, 11·50; volatile matter, 82·50; ash, 6·00 = 100·00.

Dr. Percy gives an analysis of peat, as—carbon, 58·69; hydrogen, 6·97; oxygen, 32·88; nitrogen, 1·45; ash, 1·99 = 100·00.

Bischof gives the mean of 67 analyses of coal, as—carbon, 82·2; hydrogen, 5·5; oxygen, 12·3 = 100·00; and of lignite — carbon, 72·3; hydrogen, 5·3; oxygen, 22·4 = 100·00; and of peat fuel—carbon, 80·7; hydrogen, 4·1; oxygen, 15·2 = 100. Showing the large percentage of peat fuel in its richest element—carbon—in fact the chemical value of the elements of peat, *i.e.*, dried peat, does not differ very materially from either coal or lignite.

It appears from the experiments of Sir R. Kane that the average yield of Irish peats by destructive distillation is as follows:—

1,000 Parts of Peat.

Products:—

Sulphate of ammonia	11·
Acetate of lime	7·
Wood naptha	2
Paraffin	1
Fixed oil	7
Volatile oil	3

The paraffin was converted into candles superior to those made of wax, but at too great a cost to be profitable.

A series of experiments have been made at the Commercial Gas Works, London, on condensed peat, the results of which are given below.

One ton of coal yields :—

DESCRIPTION OF COAL.	Cubic feet of gas.	Illuminating power in sperm candles.	Cwts. of Coke.	Gas per ton equal to lbs. of sperm.	Sperm corresponding to gas of Boghead Cannel, No. 2 = 100.
Staffordshire	7,100	12·42	13½	302	13·6
Derbyshire.....	7,600	11·71	17	305	13·7
Lochgelly	8,000	18·00	13	494	22·2
Derbyshire Cannel..	8,500	20·60	15	600	27·0
Wigan Cannel	10,000	20·00	13¼	686	30·9
Newcastle Cannel..	9,800	25·00	13¼	840	37·8
Leshmahago Cannel	10,500	40·00	10	1,440	64·8
Boghead, No. 1....	12,500	40·00	8	1,713	77·1
Do. No. 2....	13,000	48·00	6	2,222	100·0
One ton of condensed peat yields :—					
Belfast	10,500	15·65	8	562	25·3
Creavelea	9,240	18·75	8¾	594	26·7
Welsh	11,000	22·50	7	849	38·2

In a trial of condensed peat fuel, made by three practical engineers on the Belfast and Northern Counties Railway, with a view to test its qualities for locomotives, they report :—

In order carefully to watch the power of the fuel in the generation of steam, we rode on the engine from Carrick Junction to Ballymena, a distance of twenty-seven miles. During the whole

of the journey we had an excess of steam, notwithstanding that the fire-door was continually kept open and the damper down for the greater portion of the distance. The pressure at starting was 100 lbs. on the square inch. The commencement of the journey was up an incline of about 1 in 80, four miles long and with double curves. While going up the incline the pressure rose to 110 lbs., and afterwards rose to 120 lbs., the fire-door being open all the time. The speed, whenever this was permitted, was forty miles per hour. We noticed that while travelling the fuel emitted no smoke, and very little when the engine was standing at stations. The fire-box was examined at Ballymena and a very small portion of clinker was found, considerably less than would have come from the best steam coal. On looking into the smoke-box we found it perfectly free from cinders or dust, thus proving that the fuel stood the blast exceedingly well.

Particulars of the above Locomotive Trial of Condensed Peat Fuel.

Total quantity of Fuel used	14 cwt. 1 qr. 14 lbs.
Weight of Train, including Engine and Tender	70 tons.
Number of Carriages	7
Miles run	74
Time running	3 hours 9 minutes.
Weight per mile used of Peat Fuel.....	21·47 lbs.
Average lbs. per mile for the last three months, using Welsh and Scotch Coals at a ratio of two of Welsh to one of Scotch ..	25·25
Average for the month or May last	26·29

Mr. Forster Heddle, Professor of Chemistry to the University of St. Andrews, reports :—

I have examined and analysed the peat fuel which was forwarded to me, and have to report as follows :—

Composition, on analyses by combustion, afforded for the *dried* fuel—

Gas	60·293
Carbon (free)	31·064
Ash	8·643
	100·000

In its *ordinary condition*, however, it contains—

Water	16·74
Gas	50·20
Carbon	25·864
Ash	7·196
	100·000

It was found that a sample kept for some days under cover contained 16·4 per cent. of moisture, and that samples artificially dried regained upon exposure nearly the above amount, so that it may be held to be impracticable to improve the fuel in this respect, while the quantity cannot be looked upon as excessive. If, however, the fuel be kept under cover its condition will be materially improved.

The fuel is well fitted as a gas producer if used to mix with an ordinary gas coal.

3 lbs. of the Peat "worked off" in a small gas apparatus yielded gas at the rate of 7984 cubic feet of gas per ton. This gas was prepared precisely as in large gas works—so that the quantity may be taken as that available for application in the Hydro-carbon process, or "Water-gas process." This gas is better fitted indeed for this purpose than the gass obtained by passing steam over red-hot coke, as the gas obtained by the latter process is always much charged with carbonic oxide—a highly poisonous gas.

When examined by Lewis Thomson's Fuel Test Apparatus, the "calorific power" of the fuel was found to be—

In its usual state	4·675
When dried	5·94

that is 1 part of the fuel will boil off as steam above 4½ times its own weight of water from 212°; and the dry fuel about 6 times its own weight.

The fuel in its ordinary state yields 32·06 per cent. of coke, or about 6½ hundredweight per ton.

The coke on analysis yielded—

Carbon	78·24
Ash	21·76
	100·00

The ash was light and incoherent, and in no way checked the combustion of the coke.

This coke, when tested in Lewis Thomson's apparatus, gave a calorific power—6·743. The coke is firm and dense, and would probably serve well with a little coal for a forge, being from the absence of sulphur peculiarly fitted for such application.

The following extracted from a tabulated statement giving details of the various peat enterprises actually now working, will afford some interesting information on peat manufacture.

System.	Where Working.	Power.	Tons of dry fuel per machine per season.	Cost per ton.	Relative value to Coal.	Authority.
Hodges' Canadian Peat Company.	Montreal for Grand Trunk Railway.	16-h.	4000	6/6	5-6th or 84 per cent.	Mr. Aikman & Grand Trunk Railway.
Boston Peat Company, U.S.A.	New England States.	12-h.	4200	8/-	84 per cent.	Mr. Leavitt.
Roberts, Pekin,	New York.	13-h.	3500	8/- to 9/-	84 per cent.	Mr. Leavitt.
Haspalmoor, Colbermoor.	Bavarian Government Works.	Not stated.	Not stated.	12/-	60 per cent.	Irish Commission.
Box's	On trial.	16-h.	stated 4/8	—	—	Pamphlet and Letters.
To which we may add						
Clayton, Son and Howlett, London, W.	England, Scotland, Ireland, Wales, and Germany.	6-h.	3500	3/6 to 5/-	Variable according to quality of peat.	Selves.

From the foregoing it will be seen that the peat fuel possesses a calorific power of 5-6th of coal, and can be produced in Canada and the United States at from 6/6 to 9/- per ton, where wages for labour are not lower than 7/- per day.

APPENDIX.

From "The Engineer," January 30, 1874.

PEAT IN GERMANY AND ITS COST.

The prominence which the peat question has lately received from the engineer, the capitalist, and the general public, induces us to lay before our readers the following extract from the *Allgemeine Deutsche Politechnische Zeitung*, as affording an opportunity for seeing what is done in the matter abroad.

Herr Busch, a landed proprietor in Gross-Massow, near Lauenburg, appears to be carrying on the peat industry on his own estate, and communicates to our contemporary that he was delegated by the "Lauenburg Branch" of the "Pomeranian Agricultural Society" to examine and report upon a new peat-press constructed by Stuetzke Bros., jun., Lauenburg, which commanded at the time considerable attention. He reports the machine to be exceedingly simple in construction, capable of working up all manners of peat, requiring little power and almost only juvenile attendance. The price of the same seems to be somewhere between £20 and £25.

"The peat-press consists of a wooden tub about 6ft. high and 2ft. wide, chained upon a kind of sledge. The wooden vessel contains an upright shaft which may be set in motion by means of a horse gear. This shaft carries on the bottom an iron disc, above it two revolutions or turns of screw-blades, and above these four similar blades, each forming a quadrant, and so arranged that they form a complete revolution. Knife-like projections in the wooden vessel prevent the peat revolving with the blades and shaft; the opening for the introduction of the raw peat is at the back on top; in front is the iron delivery, which may be opened by means of a lever, and contains a wooden conical mould, through which the peat issues in four endless strings or streams on an inclined table, on which it is cut in pieces or blocks of convenient length. The whole of the parts of the machine are so constructed that repairs are reduced to the very minimum. The machine requires one horse, three adults, and three or four boys or girls, according to the size and distance of the drying ground. If the peat to be worked lies entirely under water, or has otherwise been rendered very soft or wet, it must be thrown up to dry a little; in the same way has it to be wetted if too dry. As a rule it may be operated upon just as dug from the bog after removal of the top layer, but if the quality varies much at different depths it is desirable to mix the same in digging and throwing out. Two men dig

the peat and cart it to the machine, which is placed as close as possible: a third feeds the machine, taking care to keep it constantly full in order to facilitate the even discharge of the streams of moulded peat. If the latter cannot be moved forward on the wetted table without getting crushed and squeezed, then the pulp is too wet; if it crumbles it is too dry: if the stream be uneven or incomplete the mould is clogged, and may be opened at once and the obstruction be removed. Very little practice overcomes and entirely avoids these difficulties. A girl or boy stands on the left-hand side —from the machine—of the table, and cuts from the stream with a sort of wooden spade 4in. square—while holding the former with the left-hand—a length of 10in., and removes the same to the end of the table, from whence it is loaded on a cart by one of the remaining two or three children, and wheeled to the drying ground. If there is sufficient room the pieces are simply laid side by side in a dry atmosphere. Three days suffice to air-dry the same, and in two or three weeks they can be stowed into large heaps. The writer here repeats that peat having gone through this machine dries much more quickly and burns with greater intensity of heat; also that the lightest and poorest stuff so worked is fitted for consumption under steam boilers. One volume of this press peat is equal to about two of Hanover peat, or to three of ordinary cut peat, and the intensity of heat developed stands in the same proportion.

One horse is sufficient for ten hours' work per day, the dynamometer only showing 80lb. to 95lb. on a beam 13ft. 6in. long, according to the size of the mould and the condition of the raw material, making two rounds per minute at thirty-seven paces each, or a total of seventy-four paces per minute, the exertions of the animal not lying so much in the intensity of the pull, but in going round in a circle, and this one can do easier than another. Next to the regular speed of the horse the production of the machine depends on the size of the moulds used. No. 1 is 3½in. square, and produces in fifty minutes—during which the horse makes 118 rounds by exerting a pull of 80lb. on the 13ft. 6in. beam—1,000 pieces of peat 10in. long, containing 122,500 cubic inches = 70⅞ cubic feet of wet peat. Absolutely dry, one of these pieces weighs 1lb. loth.—1lb. ½oz., or rather more, in English. No. 2 is 3¾in. square, delivering in one hour and five minutes and 150 rounds of the horse, 1,000 pieces of peat 10in. long, the dynamometer showing 85lb. to 88lb. on the same length of beam. The bulk of wet peat thus delivered is 81¾ cubic feet, one piece weighing 1lb. 17 loth.—say 1lb. 8½oz. English, rather more—when absolutely dry. Mould No. 3 is 4in. square, and delivers in one hour fifteen minutes, 144 rounds of the horse with a pull of 92lb. to 95lb., the same number of pieces, viz., 1,000 also 10in. long, being 101¼ cubic feet wet peat, which weigh when quite dry 2lb. ½oz. each piece. Some cut the peat only 8in. long, others 12in.; 10in.

is the best result of a number of trials. He uses form No. 3. His hands have to produce 7,000 pieces per day, and he pays 6sgr. (7·2d.) per 1,000; for turning over or restacking, 0·6d. per 1,000 each time. He turns his peat over three times, and pays 9d. per 1,000 in the stack, but this extra expenditure is more than covered by the greater value of the product and the saving of carriage by reason of the reduced bulk. Peat thus prepared from the 1st to the 20th May proved excellent fuel in the writer's steam distillery.

We shall only add a few remarks to the above translated extract. The apparatus in question certainly seems so simple, judging from the description given, that it would, perhaps, be impossible to excel it in that quality; at the same time it appears to us to be capable of further development. Of course it would be easy enough to adopt the same for and attach steam power, since the horse gear only seems to be the special requirement of the manufacturers there who may have horses to spare at the time they carry on the manufacture. Assuming, however, as we ought, that the apparatus answered all practical purposes, let us just make a comparison of weight and cost.

Herr Busch, we are sorry to see, omitted to give any data as to what bulk the material is reduced to when dry, but this is not very material, 7,000 pieces of form No. III., at 2·06lb. each, which, it will be seen, leaves a margin of 1,000 per day for loss of time, gives a daily production of $6\frac{1}{2}$ tons as near as possible, for which Herr Busch pays $7 \times 9 = 63 =$ 5s. 3d., or say 10d. per ton, to which must be added the cost of the horse-power and the use of the machinery. This is so low a figure that we need not stop to consider the latter, but attempt to estimate the cost of production according to English prices. The motive power required would be $\frac{95 \times 13{\cdot}5 \times 2 \times 3{\cdot}14 \times 144}{75 \times 33{,}000} = {\cdot}46$, or less than half a horse-power; but we will allow one-horse power, and say it requires 11lb. of coal per hour, or 1 cwt. a day to produce it. This is a high estimate, but small engines consume more fuel per horse-power than larger ones; in this case it would cost nothing for coal at all, as peat would be used as fuel; but we will estimate the value per day at 1s.; three men at 3s. 4d. per day each, 10s.; four boys at 1s., 4s; total, 15s. cost of $6\frac{1}{2}$ tons, or, say, 2s. 4d. per ton for wages and power, exclusive of outlay and repair of plant and the value of the bog, but 3s. per ton would cover all amply. Now if peat is worth half the price of coal of medium quality, we should have the equivalent of one ton of the latter for 6s., exclusive of profit to the producer and carriage.

Now these figures prove beyond question that peat may be profitably prepared and brought to market by the capitalist, as well as economically used by the consumer. In the encouragement of peat industry the question of cost stands in front, and it is especially the query whether coal will at

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[illegible] I [illegible] to make a [illegible] of [illegible] [illegible] [illegible]

Mr. AITKEN said he had listened with great pleasure to the very instructive paper which Mr. Plant had read. If he were to find any fault with it, it would be because he has not given us exactly the commercial information which we desired. If he had gone more extensively into a comparison of the prices at which these peat fuels can be produced and sold, with the prices at which coal in the various districts where they are produced can be sold, we might have seen whether these inventions, which at first sight appear to be very important, could be practically worked, and were likely to confer those benefits upon the country which are claimed for them. Mr. Plant has given us the prices, in several instances; but so much depends upon the localities in which the fuels are manufactured, and the demand existing for them, that the price per ton does not convey their exact commercial value.

As their ultimate success depends upon two essential points —first the cost of production; and, secondly, their value as heat-producers — some fuller information on those points would have been acceptable. The gratitude of this country is due to those who are bringing forward, and trying to perfect, these inventions; for the commercial greatness to which England has attained is due in large measure to our cheap fuel, and to the manufactures that have been led to concentrate themselves round the various coalfields in consequence of that cheapness. Our position is now greatly altered, in this respect, fuel has become very expensive—so much so as to endanger the commercial supremacy of England—and these attempts to introduce peat fuels, and to utilise the waste slack of the collieries, is of great importance to every coal consumer. It is to be hoped that eventually means will be found of making these peat fuels and made coals more extensively useful than they have hitherto been; and

we may find them coming into successful competition with coal, so that the great dearth of fuel which is anticipated may be, if not entirely averted, at all events indefinitely postponed.

Mr. Traice said it had always appeared to him that the commercial success of peat fuel depended primarily upon some simple means of getting rid of the water, which forms about 70 per cent. of the mass. The plans proposed generally appeared to be inadequate for the purpose, or too expensive. The commercial question must be purely one of this kind: first, What shall be the cost of the most economical mode of collecting the peat and ridding it of its moisture, and then of bringing it into a shape convenient for carriage; secondly, What would be the cost of conveying it to the places where it can be used; and thirdly, How far it has the same advantages—that is, gives a fire of the same quality, whether for furnace or domestic uses—as coal? As yet, the matter seems so much in its infancy that we cannot form any decision upon these questions; but our thanks are due to those who are exercising such ingenuity and spending so much money in trying to solve these problems. There is one point to which you have referred, and on which the matter wears a much more practical aspect—that is, with reference to the conversion of peat into an equivalent for charcoal. The production of the very finest iron, for a time, threatened to become almost impossible through the extinction of our forests, which were swept away in order to produce charcoal; and a great deal of the best iron, for a long while had to be imported from Sweden and other places where forests were still accessible. Of course, it may be said our coal is a mineral charcoal; but it is a mineral charcoal, generally speaking, largely combined with sulphides in some form prejudicial to

the working of iron, they convert the metal into brittle sulphides of iron. If it should turn out that the charcoal produced from peat is, as is stated, free from sulphur and phosphorus, the invention will be one of the utmost value, there will be a strong probability of its coming into use in that way, which will I believe open up an unlimited field for sound enterprise and for great profits.

Mr. PLANT, in reply to the remarks as to the commercial value of these peat fuels, stated that it was a point upon which the inventors or owners of the peat manufacturing machines spoke with praiseworthy caution, or were altogether reticent upon; in fact, it was reasonably a difficult matter to speak about its price in the market, for it may be said that both its manufacture and its use had scarcely advanced beyond the experimental. It had been shown by one inventor that peat could be made into a good fuel at the low cost of 2s. 6d. per ton; also that a ton of peat charcoal could be produced at a cost of 15s. per ton; that the heating power of peat fuel was just, weight for weight, one-half that of coal. In one place where it has been manufactured, the price of peat fuel on the spot has averaged one-third the price of coal in the locality, but the addition of the cost of carriage when sent to a distance soon diminishes this favourable comparison between it and coal. In places in Great Britain where coal is scarce and dear, and peat abundant, peat fuels could very well be sold at a good profit; but where, as in Lancashire, coals are plentiful, the chances of peat fuel in a competition are very small.

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TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART 4. VOL. XIII. SESSION 1873-4.

At the ORDINARY MEETING of the members, held at the House of the Literary and Philosophical Society, George Street, on Tuesday, 31st March, 1874.

THOMAS KNOWLES, M.P., President, in the Chair.

There were twenty-five members and visitors present.

The following donations to the Library were announced:—

From the Literary and Philosophical Society of Manchester: Proceedings for 1869-70-71, and Vol. IV. of the Memoirs.

Mr. TRAICE then read the following paper:—

COAL-CUTTING MACHINERY.

BY MR. W. H. J. TRAICE.

When my friend Mr. JOHN PLANT requested me to read a paper on Coal-cutting Machinery to the Manchester Geological Society, I hesitated on the ground that the subject is one that can only be adequately treated by an experienced mining engineer. On further conversation, however, and with the understanding that a general notice of this comparatively new element in mining operations would be acceptable, and might be considered as prefatory to more detailed expositions of various contrivances for the mechanical extraction of coal, I readily consented to under-

take this very humble task. The tendency of industrial production in all its developments is to supplant the heavy labour, which is little more than the exercise of brute power, by mechanical appliances, in which the forces of nature are enlisted in our service. In some departments of mining work this exchange has been made effectually, and with great advantage to men and boys, to coalowners, and to the public. The winding-engine has taken the place of the horse-gin; the pony is now enabled, by the convenient laying out of roads, to do a large proportion of the underground haulage, formerly the exacting labour of boys, girls, and women; self-acting jig-brows effect a further saving of labour, and the various arrangements by which the steam-engine, and of late the compressed air-engine, impart motion to metal ropes for raising the waggons from the deep inclines, and also to supersede, in many cases, the patient quadruped, are interesting examples of mechanical inroads in the recesses of the mine. If the collier has not been relieved from the severest, most exacting portion of his labour—the holing or undercutting the coal—the delay cannot be attributed to the indifference of inventors to the problem of cutting coal mechanically, nor, I apprehend, to any lack of invention. I have had the curiosity to look up the specification of a coal-hewing machine, patented by Michael Meinzies, of Newcastle, in 1761. The implement he proposed to actuate was a miner's pick, and he would have transmitted the power from the bank by spears and chains; a fire-engine, which we now call a steam-engine, "a water miln, wind miln, or horse-gin," having been the motor he proposed to use. He mentioned the use of a saw as well as a pick in cutting the coal, and also a wheel, with a pick on its periphery for shearing or vertical cutting. He further proposed a cutter to be worked by a man turning a crank. I

believe this was not Willie Brown's "iron mon," spoken of by old pitmen in the north; but I have not met with any description of this personage. In the century that followed Michael Meinzies' invention, it is stated that upwards of 100 patents were enrolled having the same object. I have met with references to some of these, and believe several reached the stage of trial, and were even in use for short periods. Mr. Jeans, in his able paper, recently read before the Cleveland Institute of Engineers, having referred to Michael Meinzies, says:—"In 1762 another patent was taken out for cutting coal by machinery, the next patent was taken out in 1783, and the next in 1818. . . . . other patents followed in 1830, 1843, and 1846 respectively. From 1846 to 1852 no fresh patent was taken out, but between the latter year and 1864 no less than twelve new patents were taken." This would seem to throw discredit on the current statement that 100 coal-cutting patents were taken out between 1760 and 1860; but it may possibly be reconciled by the practice, formerly in vogue, of making a specification a net broad enough to cast over every possible or impossible application of an invention, the securing an exclusive right to which was, as I well remember, such an anxious and costly business. Perhaps, too, if we included contrivances whose authors never sought the protection of the Great Seal for the offspring of their ingenuity, we could make up our century of coal-cutting inventions and have some to spare, all sadly laden, too, with "the hope deferred that maketh the heart sick." Whenever the history of coal-cutting machines comes to be written, I think its practical chapters will not go much further back than the year 1860; the value of the ideas embodied in previous inventions need not be ignored—indeed, many of them have been revived in subsequent appliances, but this period roughly marks the turning point when the introduc-

tion of such machinery, instead of being viewed askance, began to get regarded as a possibility by the mining world. The mechanical problems to be solved are:—First, To contrive a machine that will cut a groove beneath the coal to a depth of about three feet, such groove not to average more than three inches in height. Second, To make the machine so compact in height and area that it can be adjusted handily in the spaces where it has to work. Third, That the weight of the machine should be such that it can be readily moved from one place in the mine to another, and yet that it should be so strongly constructed as to bear the strains and ordinary casualties incident to its work in a coalpit. Fourth, That its progressive movement when at work should be automatic, or very easily effected if done by hand gearing. Fifth, That the machine should not require more than two or three to attend to it, and do all the work incidental to its operation. Sixth, That it is very desirable to have machines adapted to cut in other than horizontal planes, and at various heights from the floor. Seventh, To employ a motive power for driving the machines that can be applied in any part of the mine. It is almost superfluous to add that all these conditions may be fulfilled, and by various descriptions of machines, and yet mechanical coal cutting remain a problem virtually unsolved; the inexorable law of demand and supply cannot be evaded, and only when machines do the work more economically, and so more profitably, than it is done at present, can their inventors hope to see them generally adopted in the extraction of coal.

We may group coal-cutting appliances by their cutting tools; by the construction of the engines which work them; by their adaptability to various kinds of work; by the motive power, and by many subordinate but most important details of arrangement; but as yet the cutting implements

offer the broadest and most characteristic basis of classification. As far as my inquiries have gone, the actuating a pick mechanically, as much as possible in the style it is so vigorously wielded by the hewer, has engaged by far the most attention in attempts to cut coal by power. This is a natural, but apt to be a very fallacious, direction for invention to take; for uniformity, or diversity within a certain very narrow range, is of the essence of mechanical action; whereas infinite variety of movement and adjustment of limb and muscle to varying circumstances, and these, guided by intelligence, are endowments the birthright of every unit of our toiling millions. I have already mentioned that Meinzies' coal-cutter was a pick, and a glance through the specifications of the last fourteen or fifteen years familiarises us with the names of numerous inventors who have devoted themselves to the perfecting the machinery for using this instrument, or increasing the efficiency of the tool itself. Mr. William and Mr. Samuel Firth appear to figure most frequently in these claims for patents, to secure them the advantage of improvements in pick machines, and, without professing to give the names of all who have exercised their ingenuity in the same direction, I may also mention Messrs. W. & G. Donisthorpe, Rothery, Jones, Nisbett, Sturgeon, Carrett, Hurd, Warrington, and Leatham as occurring most frequently in my notes. I may just indicate some of these modifications, as the making a shallow cut with a short-shafted pick, and repeating the cut to the necessary depth by one with a longer arm; the having two picks of different lengths working simultaneously; the using a spring to drive the pick, the piston only drawing it back; the cutting outward instead of inward; various contrivances to clear the hole of dust and *débris* to free the action of the tool; the making the actual pick a moveable cutter fitted into the heavy head of the striking arm; the

varying the centre of oscillation of the pick arm, and many other expedients to surmount difficulties experienced in practice. Invention rarely triumphs by a *coup de main;* it may effect a lodgment within the walls, but it usually wins —when it does win—by a prolonged hand-to-hand fight. It has been objected that "one-half the power necessary to work the machine is lost in drawing the pick back to strike another blow;" this is substantially true; but on the other hand, there are contrivances for utilising this back stroke to clear the cut which may make the loss of power more apparent than real. Mr. Jeans, from whom I have already quoted, admits, however, very frankly, that the pick machine has the recommendation of simplicity, and of not being liable to get out of order; the cutter arm being driven by a bell-crank motion from the piston, nothing can be more direct than its action. I also think it probable that the sharp blow or impact of the pick is likely to be more effective with some kinds of coal than a chipping or sawing action. The disc, or circular saw cutter, though suggested in Meinzies' patent, does not appear to have commended itself to inventors at an early period in the progress of mechanical coal-cutting. I find that something analogous to the circular saw was patented by Hemingway in 1861; it consisted of three very broad arms, having cutters at their extremities, and it revolved excentrically; I am not aware whether it was actually tried. The principle of a horizontal disc cutter was adopted in the patent of Mr. J. S. Walker, taken in 1869; but it appears to differ from those now actively inviting public attention, inasmuch as while the axis of the former was within the frame of the machine, and it could only cut to about the depth of its semi-diameter, the latter are contrived to work their way almost entirely beneath the coal. All the machines now on view at The Exhibition of Appliances for the

Economic Consumption of Fuel are of the class last referred to; three are of the type patented by Messrs. Hurd & Simpson; of these one is manufactured by Messrs. Goodbrand & Holland, and two by Messrs. Mather & Platt. In these machines the disc or saw cutter is carried by a gib pivoted on the end of the machine, so that it can be used to cut direct ahead or on either side. The chisels or cutters, corresponding to the teeth of a saw, are moveable and readily changed when blunted or broken; this is an arrangement common to all such machines, and the cutters themselves can be forked, pointed, or of any form best suited to the work generally, or to the special nature of the coal, dirt-band, or shale to be cut. The disc is mounted somewhat excentrically, and a self-acting feed motion keeps it up to its work. These machines are designed to be driven by compressed air, which, as we shall subsequently have occasion to notice, is now the most usual mode of conveying the power from its source.

Another rotary coal cutter at the Exhibition is that of Messrs. Winstanley & Barker; it is designed like Hurd & Simpson's machine, to work on the ordinary rails; the cutter disc is driven by a pair of oscillating cylinders, having a pinion on the crank axle, which directly gears into the broad notches between the teeth; a small segment of the disc remains external to the face of the coal. The cutter wheel in this instance is mounted beneath the frame of the machine, and can only cut on one side. It cuts its way into the coal till at right angles to the frame, when the man or boy in charge slowly works it along by a chain and crab.

The third example is the Patent Rotary Coal-cutting Machine of Messrs. Gillott and Copley, exhibited by Mr. J. G. Bass, of Sheffield. This is only illustrated

by a model arranged in position as if alongside the face of the coal. It is driven by a pair of cylinders fixed on the frame of angle iron, and from the crank axle of which motion is indirectly imparted to the vertical pinion that gears into the slots in the cutter wheel, which is carried by a gib or bracket. It moves along the face as it cuts, pulling itself by a small wire rope, the speed of progress being easily adjustible.

The endless chain cutter was, I believe, first proposed by Mr. William Peace, of Haigh, in a patent secured in 1853, and has since undergone many improvements and modifications by Messrs. Gledhill, Firth, F. Hurd, and Alexander Baird, and possibly by other inventors. A gib or arm similar to that which carries the circular disc cutters is pivotted to the side or end of the engine frame. There are pulleys at each end, around which works an endless chain, kept in place by flanges, and with tightening adjustments. This is a sort of pitch-chain, or one made up of link stocks, into which cutters are fitted. When the chain is kept at work on the face of the coal it makes a nearly straight cut at a right angle to the face. In the various machines of this class that have been patented much ingenuity has been bestowed in surmounting difficulties and making adaptations. The driving pulley is either beneath the machine or close alongside it, at the inner end of the gib carrying the cutter chain, and can obviously be driven by a pinion working directly, or through gearing, from the crank axle. Mr. Frederick Hurd patented in 1869 quite a *bijou* chain cutter, the link stocks consisting of a series of ingeniously contrived hooks that need no pins or rivets, and in which the cylinder is carried on a telescope-jointed prop to fix vertically while the cutter is at work. The gib or carrier works radially at any angle, and the whole affair does not weigh 2½ cwt. Of

course this could be employed to cut a block of coal on all four sides if required to do so. Again, Messrs. Firth and Hurd use a wire rope in place of the link stocks, the tension of the rope being maintained by a sort of elastic clip pulley; the cutters in this case are made in sections to embrace the rope. A coal cutter of this class, the invention of Mr. A. Baird, of the Gartsherrie Ironworks, and designated "The Gartsherrie Coal-cutting Machine," has very recently formed the subject of an excellent paper, given by Mr. Jeans to the Cleveland Institute of Engineers, and to which I have already referred; as it appeared in most of the mining and engineering journals about a month ago, it is easily accessible, and I can recommend it as a very clear exposition of the subject.

I believe I do not err in stating that these three types are as yet representative of the machines that have had such an amount of trial as to bring them within the scope of practical consideration. There are, however, many more that are not unlikely to be found capable of useful application; for the varieties of density, of toughness, or friability of coal, pyrites and dirt-bands offer, I fancy, a wide range for the inventor who essays to adapt the machine to its work. The slotting machine made by Messrs. Carrett & Marshall excited much notice a few years since; it was intended to be used by the dead thrust of an hydraulic ram, and it cut like the tool of a planing or slotting machine. It could, however, be used by percussion. Mr. Andrew Howarth has a slotting machine in which the cut is made by a chisel driven into the coal or floor, and which is moved forward after each cut, its action being analogous to the morticing machines for wood work.

Straight instead of circular saws have met with favour among many inventors, and those too who are not novices in the work. Mr. G. Simpson patented, in 1870, a cutter

consisting of a straight bar to project at right angles from the machine, having moveable chisels set along the side next the coal, and which is worked by a reciprocating action that, of course, need only consist of a foot or so of longitudinal movement; a feed action keeps the saw up to the coal. There is an arrangement of this kind, but I cannot at the moment say if it is by the same inventor for fixing the saw in vertical as well as horizontal planes; in which cases it could be made to hole the coal at the sides as well as the bottom and top. Mr. Andrew Knowles, in 1869, patented a machine of this straight saw class, but it is designed to undercut the coal along the face; to use it two narrow bays, or one if there is an open end, must be formed; the machines to move the saw to and fro parallel to the face, are placed in these bays, and the saw is moved reciprocally as by a pair of sawyers making a cross-cut.

In addition to these modes of operation, there are a number of contrivances for using drills or stocks having circular or other cutters set at intervals along them; these are made to effect a sort of lateral drilling action, again similar to some of the wood morticing appliances, and one of the latest of such machines, that of Mr. W. J. Clapp, of Nantyglo, has a series of drills which are driven in to the coal simultaneously.

I neither profess to have given all the types of machines that have been offered to the colliery proprietor, or mentioned the names of all the gentlemen who have invented or improved them, but I believe my view is for such an occasion sufficiently representative.

Perhaps I ought to add that there are numerous inventions as to the details of construction of the machines; of their mode of working on the rails, of clip pulleys and other expedients for steadiness or fixture; of progressive movements, automatic or by hand gearing; but every one

familiar with practical mechanics will know that there must be an infinite number of such things suggested and contrived to obtain smooth and efficient working.

Coal Breakers.

I think it right to refer very briefly to a class of tools which have attracted much attention—those known as Coal Breakers. The frequent accidents occasioned by the use of powder in blasting have raised the question whether much, if not all, the work done in the mine by this powerful but dangerous agent could not be performed mechanically. Several inventors have attempted to accomplish this; thus Tijou and Whieldon propose to insert in a hole drilled in the coal a bit of apparatus, with a knee or toggle-joint that can be straightened by a screw worked from the face, and so exert a powerful thrust; but the contrivances of Jones, Bidder, and Chubb, in embodying the principle of the hydraulic ram applied directly, or through the intervention of wedges, appear most likely to effect their object, and I believe such tools are in use in several collieries. Mr. Sturgeon, whose inventions are numerous in relation to colliery work, has also a plan for coal breaking, which is an adaptation of the hydraulic ram; but he has also claimed to supersede gunpowder by the application of something like the hydrostatic bellows. He would stuff an empty bag or a coil of flexible pipes into a hole made to deposit them; in either case the material must be strong enough to resist great pressure; he would then fill either with water by a force pump, and as it filled the expansion would, it is assumed, burst off or down the mass to be removed.

Compressed Air Engines.

The progress of mechanical coal cutting has been retarded through the absence of power in the mine

suited to actuate the machines. Above ground, whenever we wish to try anything new, we can have power at once from the steam engine; a steam pipe and a donkey engine give us facilities for making any trials we desire, and with little or no disturbance of ordinary work. But there are numerous mines that have no steam engine underground, and when there is one it would obviously never do to have steam blowing off in the narrow roads and spaces of the mine; it would make them insufferably hot, and interfere with the ventilation, besides being intolerable to work in. Some inventors have proposed to use hydraulic engines, either worked by pressure from water brought down the shaft in pipes, in which case it would all have to be raised again to the surface; while others, as Carrett and Marshall, would employ an underground steam engine to drive the water to the working-place, when it would be returned by drain pipes and used over and over again. But there seems now to be scarcely any doubt that the best medium for conveying power to the coal-cutting engines is compressed air. Pumps for its compression can be worked by steam engines on the bank, and the air condensed into strong receivers at a pressure of four or five atmospheres, or more—from 60 to 80 lbs. on the inch; and from thence it is conveyed by iron pipes down the shaft and laid along the main roads, and up to the levels of the mine, and from these conveyed by flexible pipes of india-rubber-varnished cloth to the coal-cutting engines. I ventured to say, seven or eight years ago, that there would be no coal cutting by machinery till it was deemed worth while to put up air-engines; and colliery proprietors were unlikely to do this while yet such machines were in their experimental stage of existence. But I also made the very obvious remark, that if once put down to actuate coal cutters, the compressed air that could be carried to any

part of the mine would soon be turned to many uses—as for haulage, local pumping, drilling, and, indeed, for any purpose requiring power. I find that, in fact, this which I then suggested as a secondary application has, in many instances, become the primary object of having air engines. I asked a friend, a mining engineer, to obtain for me any information respecting the use of air engines for haulage and other underground work. I hope it will not be deemed invidious in giving the name of the manufacturer of these engines who is good enough to supply me with the data—it is Mr. T. A. Walker, of the Globe Foundry, Wigan. I find from his statement that the firm has upwards of forty of its air engines in use at collieries in Lancashire, Yorkshire, Wales, and Scotland. As to the work done, I may cite some of his examples:—One pair of air engines haul up a brow 800 yards long and inclining 1 in 4; and there are three others used at the same colliery; another pulls the waggons up a brow of over 800 yards, with a dip of 1 in 2½, and works two other roads at the same time. This pair of engines, having 18-inch cylinders, with 3 feet stroke, haul about 600 tons a day, the average load being seven or eight tubs, of about 8 cwt. each, drawn at a speed of six miles an hour. The average working pressure is from 25 lbs. to 30 lbs. on the inch. Then a pair are winding coal up a small pit 30 yards deep, and at a distance of 1,600 yards from the main pit, the air actually travelling 1,800 yards before it gets to its work. There are several other equally striking examples, but I must not dwell on them, and will only add that Mr. Walker states—and I find he is confirmed by Mr. Firth and others—that distance makes no practical difference in the working of the air. It is, however, found advantageous to have air receivers placed at distant points in the mine. The names we are familiar with in the invention of coal cutters also take a prominent

place in devising or improving air pumps or compressors, and the receivers for the air. Messrs. Firth, Walker, Hurd, Simpson, Donisthorpe, Sturgeon, and Jones are well known in connection with this kind of work; less so Messrs. Brown, Paraire, Richardson, and Baird. Mr. Sturgeon has lately patented an air-compressor having several novelties of construction; he as carefully avoids the admission of water to the cylinder as others provide for its presence in small quantity; and while the valves usually work by pressure, he actuates them mechanically, and so proposes to avoid a difficulty, of which Mr. Jeremiah Head recently spoke, as having been experienced with the air machines in use at the Mont Cenis Tunnel. I may just state that, as in the steam engine we are most solicitous to preserve the heat, in the air engine we want to get rid of that incidentally generated in compressing the air. For example, if air at 39° Fahr. is compressed to a fourth of its original volume, it will be raised to a temperature of 419° Fahr. Water is used to take up this heat, but owing to the large capacity of water for heat, weight for weight, as compared with air, and as the latter, the water, is about 800 times heavier than the former, it is clear that a small quantity of the liquid will take up the heat from a very large bulk of the air. I hoped to go into some little detail on this subject, but it would most unreasonably prolong my paper; but I must not omit to call attention to an air compressor, at the Exhibition, of Messrs. Hurd & Simpson, and made by Messrs. Mather & Platt; it is a very compact machine, and intended to be driven by a horse-gin in the mine itself. Mr. F. Hurd also proposes to use a vertical lever, or inverted pendulum, to fall out of the perpendicular, and so increase the pressure, at the moment of greatest compression of the air. There is a considerable loss of power when the compression of the air intervenes between the steam engine

and the air engines below, but this will probably be much reduced; and in the meantime it is stated that from 40 to 50 per cent. of the original power is realised. It will probably be found that the loss of power represented by the heat of compression may be in some measure compensated by the higher temperature of the mine which will increase the elastic force of the air in pipes and receivers. Something should also be said for the cooling of the air by the escape of the exhaust from the cylinders of the coal cutters, and which, in expanding, takes up so much heat as to reduce the temperature by 2° or 3°; the supply of fresh air may also be considered clear gain to the ventilation, however moderate the addition.

I will now quote a few results which I give just as I find them stated, adding in each case my authority. At the trial of Mr. Firth's pick machine last year at West Ardsley, Mr. Bramwell, C.E., reported to the Mechanical Section of the British Association, that "the machine did its work with the most perfect exactitude, cutting a horizontal groove instead of the inclined groove cut by hand labour, and wasting, therefore, the minimum of coal." The rate in which it travelled in the Middleton seam was half a yard forward by one yard in depth of cut in each minute of time." Mr. Firth himself claims cutting 20 yards in length an hour, holed a yard deep; but in practice he considers 10 yards an hour a fair rate.*

* I select the following data from a paper read to the Cleveland Institution of Engineers, by Mr. William Firth. With respect to the difference in the amount of manual labour in hewing by hand or machine, a day's work is taken, in which the get is 60 tons ("which would come out of 45 yards of machine working)."

Men cutting, filling, timbering, drilling, road-laying, blasting, and all needful work, up to filling the corves..	30 men	
With machine—a man and two boys, equal to..	2 men	
All other work, up to filling corves	15 „	
		17 „

The following

Gillott & Copley claim for their rotary saw cutter a fair average of 30 yards per hour, holed 3 feet 4 inches deep, and with 27 lbs. per inch pressure in the air engine.

Winstanley & Barker state that their disc cutter will hole 30 yards per hour, 3 feet deep, with a pressure of air of about 25 lbs. on the inch.

In a paper recently read by Mr. F. Hurd to the North of England Institute of Mining Engineers, that gentleman, speaking of Hurd & Simpson's coal-getting machine, states that "In the perfected machines which are at present in use, the speed of work with a pressure of air of 20 lbs. to the square inch, may be reckoned at 30 yards per hour in medium hard coal—the groove made being 3 inches deep and a yard wide. Taking stoppages into account for removing and adjusting the machine, the average may be taken at one-third less."

The Gartsherrie, or chain cutter, is stated by Mr. Jeans to have worked for a considerable time at the rate of 300 to 350 feet to a shift of eight hours—say 14 yards an hour, and representing about 75 tons of coal.

I must here close this very discursive view of these mere mechanical applications to relieve rather than supersede

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are abstracts from reports on the working of Firth's machines :—

Park Lane Coal Company, 4th March, 1874.—The average of 12 hours was 6 yards 20½ inches per hour, holed 39 inches, including all stoppages, about two hours. The air pressure was 47 lbs. per inch, and the strokes of the pick about 54 per minute. The next day the average length cut per hour was 7 yards 12 inches.

Mr. Maddison, manager of Woolley Park Colliery, gives an average day's work by Firth's coal-cutting machine at that colliery, February, 1874 :—"Total length done in 10¼ hours, including *all stoppages*, 107 yards, or 10 yards 15 inches per hour. The seam is the Barnsley thick seam, and is 9 feet thick." The pressure of air averaged about 44 lbs., the strokes per minute 55, and the depth holed was 42 inches, and the width of groove 2¾ inches.

human labour. There is no likelihood of their effecting any sudden revolution in the getting of coal, for it will take long to secure confidence in their use, and establish their claim on economic grounds; but coupled with the introduction of air engines, not only to actuate them, but also do much of the other heavy work of the mine, I look forward to a vast development of these applications of mechanical ingenuity to lighten the toil of the miner, produce more useful coal, decrease the perils of coal getting, and also the cost of its extraction.

Mr. PLANT said he had much pleasure in moving that the thanks of the Society be given to Mr. Traice for his very exhaustive paper on coal-cutting machines.

The motion was seconded and passed unanimously.

Mr. DICKINSON said the paper of Mr. Traice is more a history of the coal-cutting machine than a description of the mechanical details. There is one point about which I would like to ask Mr. Traice—that is, with regard to the power of the air engines, which he named incidentally. He said that from 40 to 50 per cent. of the power of those engines is utilised.

Mr. TRAICE: I got that statement from two or three sources. Mr. Firth states it. Of course, it is entirely a matter of experience. It is impossible to say how much is utilised of the power of any machine without actually testing it.

Mr. DICKINSON: It is, of course, a matter for experiment.

Mr. TRAICE: Mr. Firth says from 40 to 50 per cent. of the power given off by the steam engine to the compressor is realised in the work. I have found the same statement elsewhere.

Mr. Dickinson: It would be satisfactory to know whether that statement is made on actual experiment, or whether it is a mere rough guess. I never myself, but on one occasion, made such an experiment. There were two of us to conduct it—a colleague of my own indicated the steam engine on the surface at the same moment as I indicated the air engine underground; but the percentage of power utilised by the air engine bore a much less proportion to the numbers which you have stated. Fifteen horse-power was exerted by the steam engine to compress the air, and one, nine-tenth horse-power was given off by the air engine.

Mr. J. S. Martin: What length of pipe was the air forced through before it reached the engine?

Mr. Dickinson: Probably 1,000 yards. It was one of Firth's machines.

Mr. Martin: I should think the length of pipe must influence it.

Mr. Traice: They all say it does not. I can understand one cause—(I put it as a theoretical suggestion)—why the loss by friction, the only loss we anticipate, is so small. It is this:—Of course the compressed air is cooled before descending the mine. Much of the heat given out by the compression of the air is absorbed by water; so, supposing it to descend at 50°, the further it gets into the mine the temperature will rise, according to the part of the mine to which it is conveyed, to 70° or 80°, and its elasticity will be increased by this warmth. Mr. Walker gives a number of examples of distant workings, and he states generally that practically there is no difference experienced at the remote parts of the works. They all seem to concur in that statement.

Mr. Clegg Livesey said he believed that a large number of experiments recently made showed that air compressed two atmospheres would give off a very much larger percentage of work than air compressed to a much higher degree; and that it might be compressed so much that you actually got little more power than was given by half the pressure.

Mr. Traice: That is theoretically true, supposing that the size of the pipes remains the same for high as low pressure.

Mr. Clegg Livesey: It is, therefore, necessary to take very much larger pipes and larger engines if you would work economically. The fact is, we do not require any heavier pipes, because a pipe, to bear the pressure of two atmospheres, will do much thinner than one to bear a pressure of four atmospheres; therefore, it is a mere question of testing them, and having everything prepared for the working of air. Then you may get off 40, or 50, or 60 per cent.

Mr. Plant: I feel interested in knowing what would be the verdict of our practical coalowners in reference to past experiments with, or practical working of, coal-cutting machinery in Lancashire. Is their experience favourable to their continuance, or are there so many obstacles in the way of the use of these machines that, practically, they are not of great value? I am sure there are members of the Society here who will be able to answer that question.

The Chairman: I am sure we shall be glad to hear the opinion of anyone who has tested these machines practically. I have not done so myself, and I have not heard favourable reports of any that have been tried in Lancashire. Several colliery owners I know have tried them, but the reports are such that I should not be induced to purchase one as yet.

Mr. MARTIN said that at the Gartsherrie pits, three years ago, he saw a machine which seemed to do its work very satisfactorily. When he was there several breakages or interruptions occurred in the chains for self-propelling; but otherwise the men seemed to speak very favourably of it indeed.

The CHAIRMAN: Those who have seen the machines at work admit that they do the work very well; but the question is—Do they do it more economically than it is done by hand labour? Some machines, I believe, require as many people to apply them as would absolutely do the work without them.

Mr. MARTIN said that in the instance which he had mentioned three men worked the machine. Each "face" was 100 feet, and it cut three faces during the eight hours' shift.

The CHAIRMAN: We must not lose sight of the fact that though there may be only three men at the machine, after the machine has done its "holeing," or undercut, if some one is required to get the coal down, some one to get it away, and the road wants taking up, re-levelling, re-laying, and propping before the machine can be applied again. Taking the work of coal-getting as a whole, it is a question which is the more economical, the machine or hand labour? because, after all, however well the machine may work, it is purely a question of pounds, shillings, and pence.

Mr. MARTIN said that in the instance to which he had referred, the coal cut was removed in time for the machine to commence another cutting on the following day. He should mention that there was a good roof to the mine.

The CHAIRMAN observed that a good roof was always necessary in the economical working of mines, with or without machines.

This concluded the discussion.

The following paper was then read:—

ADDITIONAL NOTES ON THE MILLSTONE GRIT OF THE PARISH OF HALIFAX.

By Mr. James Spencer.

The upper part of the rough rock is generally of a very variable character; the first two or three or four yards are generally false bedded, and rough worthless sandstone, next follow from eight to twelve yards or so of massive grits, gradually becoming finer in grain towards the base. This portion in the neighbourhood of Halifax is extensively used as a paving material, for which it is eminently adapted.

Directly underlying the grit, in some places separated from it by a bed of shale, but very often by a mere tracing, and sometimes without any distinct line of division, except the ordinary line of bedding, there occurs another rock, which, in this part of the country is called by the stone-miners the "Flatstone Rock." This Flatstone is the equivalent of the Lancashire Lower Flag Rock. This bed, when it occurs directly under the grit, only differs from it by being somewhat thinner bedded, for a hand specimen of each cannot be distinguished from one another, but when the flatstone is covered by a thick bed of shale it assumes a different aspect, it then becomes a true flag rock, readily splitting into flags, and often becoming interstratified by layers of shale and rag. This flag rock is found under the rough rock everywhere in this district, and is extensively wrought at various places in Stainland and West Vale, Calderdale and Wheatley Valley, but in the Mount Tabor and Moor End quarries, and on Hunter Hill, and in the celebrated quarries of Fly and Nab End it is wrought at the surface without any covering of rough rock, and forms deep quarries of some 60 feet or more in

thickness of rag, shale, and stone. Nab End is the extreme northern range of the Halifax rough rock and its underlying flag-rock; from Nab End it turns due east with a gentle dip to the edge of the Denholme Coalfield, which owes its preservation to a great downthrow of the strata.

The Fly quarries flag-rock is termed on the Geological Survey sheets the "second grit-rock", and is marked as the equivalent of the Haslingden flags. I believe that our Yorkshire flatstone is the equivalent of the Haslingden flag-rock, but why the Geological Surveyors should erect this flag-rock into a distinct division, I cannot imagine.

When I read my paper on the Millstone-grit Rocks of the Parish of Halifax before this Society,* the Survey sheet of the Todmorden district had not been published, I was not even aware that the Geological Surveyors had been in the district until last summer.

In that paper I separated the millstone-grit rocks into four divisions, separated from one another by thick beds of shale. It was with great pleasure that I saw the Geological Surveyors had done the same, and that my Nos. 1, 3, and 4 grits agreed with theirs, but when I saw that their No. 2 rock differed from mine, I determined to go over the ground again and try if I could make mine agree with theirs. But the result of my re-investigation went on the contrary to confirm my original conclusions, that my No. 2 grit was a distinct rock, separated from the rough rock above, and from the third or gannister series below, by thick beds of shale; on the other hand, notwithstanding the greatest desire to do so, I failed in procuring evidence to warrant me in erecting our flag-rock into a distinct division.

There are many excellent sections of the rough rock and

* Trans. Man. Geo. Soc., Vol. ix., p. 55.

flag-rock exposed along the edges of Wheatley Valley, and there, if anywhere, we ought to find evidence of the flag-rock being a distinct and independent rock, but I find that within the space of half a mile, and even less, there are two distinct beds of flag-rock. I have traced these beds, from where they occur in great thickness, at the base of the rough rock, to where they gradually thin away and become lost in the rag and shale below, and I have traced the beds of shale which divide them from the rough rock to where they thin away within the distance of about half a mile, and there become lost entirely in the mass of rough rock. In fact, the rough rock appears to give off at certain intervals an irregular succession of beds of shale and flag-rocks, sometimes the shale begins in the middle of a face of rough rock and rapidly increases in thickness, there is a good illustration of this fact in the cutting on the new railway to Ovenden, near North Bridge, Halifax, where may be seen a wedge-shaped bed of shale, which begins at a point in the midst of a mass of coarse grits, and in the distance of about 25 yards increases to 12 feet in thickness, the shale becoming divided by beds of rag and grit, massive beds of grit again covering the shale, about 20 feet below the shale there is about 21 feet of very good flag-rock, which lies directly under the grit without the intervention of a bed of shale.

Under the town of Halifax, and in the rough, hilly district between Halifax and Huddersfield, the rough rock is well developed, sections showing from 60 feet to 100 are often met with, and wherever it crops out from under the coal strata in this parish, it consists of thick beds of coarse grits, the upper portion false bedded, and the lower portion fine gritty ashlar, and, almost invariably at the base, the flag-rock occurs.

If we take a line from Halifax northwards, up the eastern

side of Wheatley Valley, and across the moors to the edge of Oxenhope Valley, we have the rough rock under our feet all the way, eastward of this line it dips under the range of lower coal-measures. At Denholme there is a narrow tongue of coal-strata which lies in a trough formed by one or more great faults, and the rough rock may be seen cropping out from under the coal-strata on either hand.

Rising gently to the west, it forms the bold headland of Hambledon Hill and Nab End, 1,400 and 1,473 feet respectively above the sea, from this hill a splendid prospect is laid out before the spectator. In the foreground lies the deep valley of Oxenhope, which leads down by Haworth to Keighley, further north a succession of hills and dales stretch away to the Pennine chain, and in the distance the hills of Craven form the background; Ingleborough, 2373 feet; Pennegent, 2231 feet; and Fountain Fell, 2191 feet; can be clearly made out on a bright day. To the west rises the brown and purple moorlands to Boulsworth Hill—the highest point of the Pennine chain in this district—which stands 1,700 feet above the sea level.

At Nab End and Fly quarries the upper course grits have been denuded away, and the lower and finer beds and the flag-rock are exposed, which are now, and have been for a long time, extensively quarried. In many of the quarries there is no rough-rock to be seen, but in some of those more to the east, that rock may be seen to gradually assume a flaggy nature, and to dovetail into the flag-rock, but as we go further westwards the rough-rock disappears and the flag-rock crops out at the surface. There is a bed of shale, about three feet in thickness, at the western edge, which increases to ten feet or more at the eastern side, and which extends over all these quarries, and divides the flag-rock into two parts. At Nab End the strata dip gently to the north and east, which is probably the

cause of the preservation of these valuable beds of stone, for the moorlands, for some distance southwards, are formed by a flattish saddle, which tilts the rocks to the north and south, and are devoid of both rough-rock and flag-rock. Directing our course now towards Halifax, we next meet with the flag-rock on Hunter Hill, below this hill it forms a flattish table-land from Moor End, on the western edge of Wheatley valley to Sentry Hill, on the eastern edge of Luddenden valley, below this line the rough-rock comes on again and occupies the surface, having the flag-rock at its base, all the way down to Halifax.

From the description here given of the connection of the flag-rock with the rough-rock, it appears evident that the occurrence of the flag-rock at the surface is due to the fact of the rough-rock having been denuded away, and not to its being an independent rock. It may seem somewhat presumptuous, on my part, in venturing to question the authorities of the Geological Survey, but I am bound to say that a long and intimate acquaintance with the grit rocks of Yorkshire, where the rough-rock and flag-rock are frequently to be seen dovetailing into one another, has irresistibly led me to the conclusion, that they are but different parts of one and the same rock; and that they were formed contemporaneously and conterminously.

The Section illustrating this paper traverses the eastern edge of Wheatley valley, from just above the village of Wheatley to a short distance above Mixenden, and gives in detail the variations and changes which take place in the several beds in the district indicated.

The thickness of the rough-rock and flag-rock combined is 100 to 150 feet. The shales below are about 150 feet and the second Grit about 30 feet. All the rocks in this locality, more or less, exhibit characteristics already referred to, but especially is this the case with the main bed

of No. 3 Grit, that rock in several localities shews the rough false-bedded and wedge shaped beds at the upper portion succeeded by thick beds of fine grained grits in the middle, and at the base graduating into a good flag-rock, the same dual character may also be observed in the true flag-rock which crowns the Lower Coal Measures.

In the Ringby quarries this rock is composed for some yards of false bedded fence-stone at the top, thick beds of rag-stone in the middle, and thick beds of ashlar and flags at the base; but on the eastern side of the hill the beds are much thinner and true laminated flags abound, a bed of shale runs through the whole of the hill, which is found to increase in thickness to the south-east, and from a few feet in Ringby it becomes many yards in thickness in Southowran.

I think that there can be no great difficulty in explaining the occurrence of these two kinds of rocks in one and the same bed. Elementary works on Geology tell us that coarse sand is deposited near the shores of seas, lakes, estuaries, &c., the finer particles are carried further by the current, and that further out still, fine silt or mud is deposited, this was admirably shewn by Mr. Green, F.G.S., of the Geological Survey, in his very able "Lecture on the Coal Formation," delivered at Manchester, and any one who reads that lecture cannot fail to understand how a thick bed of coarse grained grit should become, within a short distance, converted into beds of fine grained laminated flags, and that the very same beds should eventually become beds of rag and shale.

This seems to me to have been the normal mode of deposition of these sandstone beds, but here and there we meet with beds which have evidently been formed in an irregular manner, these cases can be readily accounted for,

when we come to recollect that changes of currents and levels often occurred during their deposition.

The application of the theory explained in the foregoing remarks, is, and will be more so in the future, of immense practical importance to those engaged in stone-mining, the value of stone has recently increased so much that even now it will pay to uncover old quarries, and extract the bottom stone, and the cost is likely still further to increase on account of the difficulty of extracting it. If, however, we can point out with an approach to precision the place where good stone may reasonably be expected to be found, (which appears to be quite possible,) we shall stimulate the study of practical geology, and benefit commercial enterprise.

Having endeavoured satisfactorily to prove that the so-called No. 2 Grit of the Geological Survey is only the lower portion of the Rough Rock, I will, after describing the intermediate shales, draw attention to the rock which I believe is the real No. 2 Grit.

At the base of the flagrock, a series of beds of bluish and dark coloured shales occur, from 150 to 250 feet in thickness, these are seen in great force under Nab Hill, and also in the valley of Wheatley and its deep cloughs, in Ogden, Skirden, and The Carrs, and in the ridge which divides that valley from Cold Edge, also on the eastern side of Luddenden valley, and in the valley of the Calder, from Sowerby Bridge to Elland. These shales were formerly considered to be barren of fossils, but, some years ago, I found a thin stratum in Wheatley Scar, about 90 feet below the flag-rock, which contained *Goniatites Listeri* and *Aviculopecten*. The stratum in which they occur is only about four inches in thickness, and the shells are all flattened and crushed, they occur in various sizes from that of a pea, up to two inches in diameter. *Modiola* is the next most abundant

fossil, parts of a *Nautilus* and an *Orthoceras* were met with. I found the same stratum in Ogden Clough, *Aviculopecten* were there more common than in the former locality, and, very recently, I came across the same stratum in The Carrs, near Within's Hotel; in Cold Edge I was shewn another bed at a lower level than the first, which contains several species of *Goniatites*.

Goniatites Listeri is very rarely found in the Yoredale and Millstone Grit rocks of this district, although they occur so abundantly in these shales, where above a score of species and thousands of specimens have been found. It is only when we come to these upper Millstone Grit shales that we find the *G. Listeri* occurring in great numbers, this species also abounds in the marine bed of the Halifax coal strata.

Goniatites reticulatus, which is the most common fossil in the Yoredale rocks and also in No. 3 Grit series, occurs but rarely in this upper fossiliferous bed.

These shales, therefore, seem to be the boundary line of these two species of *Goniatites* in this part at least, for I wish to guard myself from generalizing from merely local data, where one begins to die out and the other to take its place.

Towards the base of these shales there is a bed of coal which varies in thickness from two to eight inches, it extends over the whole area occupied by these shales, from Nab Hill down to the river Calder, and has been wrought at several places, including Brookhouse, near Mixenden, and Cold Edge. The shales above it are very dark and bituminous, which probably helped to deceive the people who speculated upon finding a thick bed of coal in them. A most elaborate attempt was made to find coal in the same shales under Nab Hill, mines were driven, a shaft was

sunk and borings made, but with the usual disappointing results.

It is a well-known fact amongst miners, that where there are thick beds of coal there are also, almost invariably, one or more thin seams accompanying them, and it unfortunately also happens that many miners seem to labour under the impression that the converse of this fact must also be true, namely:—that where there are thin seems of coal there must also be thick ones. And they seem to have instilled this erroneous idea into the heads of the credulous farmers and proprietors of land so thoroughly, that even now, in spite of the numerous failures, the notion is strongly believed in, even at the very places where the failures have been the most conspicuous.

In Higher Oxenhope the coal seam is a very useful guide in enabling us to trace the line of the second Grit Rock, for along the base of Nab Hill the strata is covered up by a talus of *debris* derived from the weathering of the shales above, so that it is difficult to determine the position of this rock. At Nab Water it may be seen in the water course, composed of a bed of sandstone and beds of rag and strong raggy stone, 50 feet or so in thickness. From Nab Hill to Cold Edge its thickness does not seem to vary much, but from the latter place it gradually increases in thickness to the south-west, and along the eastern edge of Luddenden valley it becomes a very important rock, and is largely quarried for building purposes.

The upper portion of Wheatley valley has this rock at the surface, above Mixenden the ground was formerly strewn with large white blocks from this bed, which have since then been cut up and used in the construction of the Mixenden reservoir and other building purposes, for which it is well adapted. It emerges from under the other side of the hill at Cold Edge and forms the surface from Lumb

Mill to the Reservoir. A great deal of the white grit has been cut up there for sets and building purposes, it covers the moor as far as Stoney Edge and Rocking Stones. It is a most beautiful clean white stone, part of this whiteness is due to the bleaching action of the weather, but its fine crystalline nature may be seen even in the heart of the quarries further down the valley, one or two of the upper layers of this rock seem to be almost entirely composed of pure quartz in minute grains, and in specimens which have been exposed to the weather they sparkle like brilliants. This rock passes from Luddenden valley along the edge of Calderdale to below Sowerby Bridge, where it appears for the last time in the cutting, midway between that place and the village of Copley, and is there seen to sink below the overlying shales. It reappears in the upper part of Stainland valley, but how much further south it extends I have not as yet ascertained. In the above cutting the band of coal with its under-clay may be seen in the shales above the sandstone.

It is a fact well known amongst geologists, that every bed of coal has under it a kind of clay, called seat-earth by miners, the seat-earth in the Third Grit series is generally replaced by a peculiar rock called "calley-stone," and which is also known as galliard and gannister rock. It varies very much in texture and colour, but it is generally a very fine grained, yellowish, hard, splintery rock, which give a ringing sound when struck by the hammer, at other times it is a hard mottled gray rock, the *Stigmaria* which occur in this calley-stone, are so well preserved that the piths are found intact in the centre of the plant, in the ordinary seat-clays the piths have disappeared and nothing is left but a hollow space along the outside of the plants to indicate their former position.

One of the reasons which induced me to keep this Second

rock distinct from those below, which are grouped together to form the third series, was the absence of the calley-stone from the strata above, and its prevalence below this rock, even on the top of this rock there is a yellowish sandstone which somewhat approaches to the character of a calley-stone, but the shales above are entirely free from it. In connection with the next sandstone which occurs below the Second Grit, there are two or three beds of calley-stone, each containing *Stigmaria* and other fossil plants. Below this sandstone there is a rock of a very peculiar character. It is a soft bluish thin-bedded stone, which, in Higher Oxenhope, is quarried for the purpose of making grind-stones, which find a market in Leeds and Sheffield. This rock and some thin strata below it are full of worm tracks, known as Vermiculites. I have traced this bed for a distance of ten miles, from Oxenhope valley down to Luddenden valley, and have found it of great service in aiding me to fix the relative positions of the rocks with regard to one another.

Another reason for separating this Second Grit from the third series is the fact of the most common fossil in the Third Grit series being nearly absent from the strata above the Second Grit; *Goniatites reticulatus* occurs in them but sparingly, while on the other hand, *Goniatites Listeri* is the prevailing fossil in the upper fossiliferous band of these shales, and it occurs again very plentifully in the coal strata above, where *Goniatites reticulatus* is rarely found.

In a future paper I purpose to treat of the Third Grit, its character and fossils with special reference to the new facts brought to light by the sinking of the shafts on Wadsworth Moor.

The rough-rock, as a rule, is very barren of fossils, but the flag-rock below is very rich in fossils, in nearly all the places where this rock is wrought, fossil plants have been found.

The *Sigillaria, Lepidodendron,* and *Calamites* are represented by most of the species usually met with in the coal measures, *Stigmaria* are very common. *Halonia* is represented by both its common species—*Halonia regulare* and *irregulare. Knorria* is not very often met with. *Ulodendron* is fairly represented. *Favularia (Sigillaria)* is frequently met with, there are at least three species.

Ferns are very plentiful in some places, the genera, *Pecopteris, Neuropteris, Odontopteris* and *Sphenopteris* have been found.

Sternbergia or Dadoxylon is the most common fossil plant in the Grit rocks.

The thanks of the meeting were given to Mr. J. Spencer for his communication, and for exhibiting specimens of the rocks and fossils alluded to in the paper.

Discussion upon the points raised by Mr. Spencer's division of the Grit Rocks, was postponed for a future meeting of the Society.

The following communication from E. W. Binney, F.R.S. was read,—

At the meeting of the Manchester Geological Society, on the 23rd December last, a discussion is reported on Mr. Dickinson's Paper, (page 29,) wherein it is stated that, "The separation between the true Permian, of which specimens are before us, and any of the beds of either the Bunter or the Keuper formation, is, without doubt very clear and well defined in some places, even in Lancashire. At Collyhurst, for instance we see the line of separation between Permian marls, which are fossiliferous, containing species of *Schizodus, Bakevellia,* and other shells, which have never yet been obtained from the overlying strata belonging to the Triassic series, that of

itself, is sufficient with all our eminent geologists to mark the true definition between these two great formations." Now without doubt any geologist would easily recognise the Permian strata by finding the fossil shells above named, but still the passage of Permian into Trias is by no means so marked and well defined as you find it laid down in books and on maps. At St. Bees Head in Cumberland the Magnesian limestone there is full of *Gervillia* (*Bakevellia*), and *Schizodus*; it passes upwards into red marls with granular gypsum, which in turn go into the upper Permian sandstone that extends down as far as Furness, and is there seen at Hawcoat and Furness Abbey overlying the Magnesian limestone of Stank, but to my knowledge no person has clearly traced this upper Permian sandstone passing into the Trias, in fact no one has seen this upper Permian sandstone in South Lancashire, so far as I know the only rock like it is that in Knowsley Quarry, alluded to by me in a paper on the Permians of South Lancashire.*

The pebble beds of the Trias near Manchester, as stated by me in the Transactions of this Society † more than thirty years since, at Newtown pass gradually into the underlying Permian marls, so you cannot tell when one formation ends and the other begins, except by the fossils, and here we see nothing of the upper Permian sandstone.

The Permian and Triassic strata are not liked by coal miners or geologists, as the former do not think them favorable for coal, and the latter do not find many organic remains in them. It is well worth the attention of the members of the Society to devote special study to the Permian and Triassic strata of Lancashire and Cheshire, and obtain more information respecting them by personal observation.

* Transactions of the Man. Lit. and Phil. Soc. vol. iii, (3rd series), p. 113.

† Binney on the Geology of Manchester, T. M. G. Soc. vol. i, p. 39.

At the ORDINARY MEETING of the Members, held on Tuesday, 28th April, 1874.

MR. J. AITKEN, F.G.S., Vice-President, in the Chair.

There were twenty members and visitors present.

The following additions to the Library were announced.

By Donation :—

Broadhead G. C., State Geologist. } Geological Survey of Missouri. Preliminary Report of the Iron Ores and Coal Fields, from the fieldwork of 1872. Imp. 8vo. 1873, with Atlas of 14 large Maps and Sections.

Broadhead, G. C. Meek, F. B. Shumard, B. F. } Reports on the Geological Survey of the State of Missouri, 1855—1871. Royal 8vo. 1873.

Hayden, F. V. State Geologist. } First, Second and Third, 1867-8-9, and Sixth Annual Reports of the United States Geological Survey of the Territories, for the year 1872. 8vo. 1873.

"Proceedings of the South Wales Institute of Engineers," No. 5, Vol. 8, Dec. 1873.

Sitzungs-Berichte, Isis. April to Dec. 1873. Dresden.

From Professor Owen.

"Description of the Skull of a fossil Dentigerous Bird." pp. 12, 8vo.

By Purchase :—

Barkas, T. P., F.G.S.

"A Manual of Coal Measures Palæontology," with folio Atlas of plates. Royal 8vo., 1873.

Geikie James.

"The Great Ice Age, and its relation to the Antiquity of Man," 8vo. 1874.

Palæontographical Society, publications for 1873. Vol. 27.

THE LATE PROFESSOR J. PHILLIPS, M.A., LL.D.

The CHAIRMAN said, before we proceed with the ordinary business of this meeting, it is my painful duty to allude to an event which has happened within the last few days, and the announcement of which has been to myself, and I am sure it must be to all a source of profound grief. I allude to the death—the untimely death—of a gentleman who has made himself a name in the scientific world, and who was not more beloved in the circle in which he moved in the scientific world, than he was, in his social and domestic relations. That gentleman was Professor Phillips, of the University of Oxford. He was one of the oldest honorary members of this Society. I believe he was connected with us for a period of thirty years, and I am sure we have all felt a great pleasure and satisfaction in knowing that he identified himself with the labours of the Manchester geologists; we deplore the untimely death of so distinguished a man. I trust this tribute of respect, which I beg to offer on behalf of the Society, will find a place in the Society's Transactions.

ON PLEISTOCENE MAMMALIA, FOUND NEAR CASTLETON, DERBYSHIRE.

By MR. J. PLANT, F.G.S.

Referring to a large collection of bones of the Bison and Reindeer, which were exhibited upon the table, Mr. Plant said:—

On Friday, April 3rd, two young men, Henry Havelock Hindshaw, and Ethelbert Ramsbottom were hunting over

the hills surrounding Castleton for plants and fossils, when by accident they loosened a quantity of debris which gave way under their feet, and Hindshaw discovered in the lowest part of the bank, several bones sticking amongst the clay and limestone sinter. After clearing away a quantity of the loose earth and stones, a good many large bones were obtained, some of them quite covered with an encrustation of lime, which had to be broken to release the bones. The largest bones brought away on this visit were the upper portion of the front of the skull and horn-cores of a great bovine animal, a large femur, and several vertebrae. The bones were shown to me soon after, and upon examination I was much struck with their appearance, and of the probability of their being the fossil remains of the extinct *Bos*, or Bison. I sent a drawing of some of them to Mr. Boyd Dawkins, for his consideration. On the 18th April, the young men visited the place again, and brought away a larger number of bones, similar to the first, as well as parts of antlers, teeth, and bones of a deer; and on the 25th April I went with Mr. Hindshaw, and made a careful examination of the locality, dug out a fine collection of bones, both from the debris and from the calcareous matrix, in which many of the bones lie embedded, making sketches and sections of the geological features, which belong to the place and neighbourhood.

The locality is on the south-west flank of the well-known Mam Tor, there is not, in its appearance, the slightest encouragement for anyone to look for bones of this description, for the place has not the slightest resemblance to caves, large fissures, or expositions of rock, which would lead anyone to suppose that bones lay there. The place is called Windy Knoll Quarry. It lies very near to the junction between the Yoredale shales of Mam Tor, and the great development of Mountain limestone, which runs far away to the

east of the locality—not quite at the junction, but a little over the boss of the mountain limestone. When you are approaching Castleton from Chapel-en-le-Frith, the low rise of the ground is evidently related to the long slope of Mam Tor, which is so prominent upon the road to Castleton. The low hill on which these bones are found is one of some interest, because, I believe, it separates the drainage of the east from that of the west, certainly the Castleton streams fall into the Derwent, and so into the Humber; and the drainage down the valley towards Chapel-en-le-Frith, from this point, flows ultimately into the Mersey.

The flanks of Mam Tor are over-spread with drift—very local in its character; and a thin coating of drifted debris is found upon the mountain limestone in the neighbourhood, and partly down the Winnats to the east; and from the red colour of the loam which is shown here and there by the wearing of the ground, there is not the slightest doubt that these drifts were originally derived from the washing and wearing of the shales and sandstones of the great escarpment of Mam Tor.

At the foot of Mam Tor, there are enormous accumulations of shaley debris, which block up the water courses, and give a broken and rugged character to the *talus* on descending into Castleton. The place where the bones are embedded presents the appearance depicted in this sketch. The limestone rocks come up from below—no great elevation, not above 10 or 12 feet at the utmost—and are overlaid with patches of loam and stones. Of course the ground has been considerably altered by excavations, which have broken into what was once a low continuous hill. I tracked from Mam Tor patches of loam lying in several recesses of a tolerably even and level slope of Yoredale shales; and crossing the valley, found that for a considerable distance, perhaps a mile, they are lying on the

mountain limestone. There is no appearance in this locality of any of those remarkable features which we often see in mountain limestone districts, called swallow holes. It is an even and regular piece of gently rounded ground, here and there, just covered with patches of redish loam. After a very careful examination of hundreds of the embedded stones of no large size, I was not able to find any that might be said to have been derived from the Yoredale shales and sandstones, they were all limestone; therefore, whilst the loam may have been derived from the weathering of the shales of Mam Tor, the gravel, that is, the stones contained in the clay—must all have been derived from the wearing of the limestone rocks over which the drifted loam had to pass.

I learn from several persons that bones must have been found in working the limestone in the locality for many years past, but they have been associated with the bones so commonly found on these mountain districts—of horses, sheep, and of cows. The quarrymen getting limestone supposed that the bones they dug out, of the gravel were at some ancient period, covered over, and were simply bones of the existing races of animals, and they therefore excited but little notice. I have endeavoured to ascertain whether it is possible for this debris and these angular pieces of limestone to have been accumulated by any process of clearing the ground for getting limestone, but its wide extent precludes any such idea. It is impossible that over an extent of about five miles, loam and fragments of limestone could have been so accumulated. The surfaces of the limestone, which are immediately covered by the debris, are rounded and smoothed in the manner we are accustomed to see surfaces of limestone, which have been subjected to long scouring by the action of water, and although I could

not find any striæ, the polished surfaces sufficiently show that there must have been an abrading force of some kind acting upon the rocks. The deepest part of the debris is about 12 feet, it extends 30 or 40 feet on the slope, away from the face of the limestone. Its sides are covered with debris that has fallen in the working, which we may call an accumulated *talus*.

The fissure is not more than three or four feet wide, which contains these bones, how far it may extend along the buried surface of the limestone can only be conjectured, but it appears as if there must be a very great length of it. In searching for the bones, masses of limestone have to be cleared away—loose masses—which have evidently drifted into the fissure. This fissure may be said to be literally filled with bones, and with pieces of limestone embedded in loam. The bones vary very much in the manner in which they are found, if they are taken from the clay, they have only the ordinary appearance of buried bones, that is the character that you may see upon many of these; but when this loam is removed and the limestone is reached, then it becomes a true calcareous sinter, holding the bones as tightly as they are held in any limestone cave floor.

It is from this evidence that I had come to the conclusion that there can be no mistake as to the antiquity of the bones, whether they are embedded on the limestone covered with this stalagmitic matter, or whether they are found loose and appear to be only ordinarily embedded in the drifted debris. The chances of obtaining more of these bones will depend very much upon the quarrymen. If they clear away the deep clay from over the limestone it will be possible to get at them. But I think there can be no doubt that we have obtained a good collection, which is now displayed before you, it is unusually rich in large perfect bones, and the discoverers may consider themselves

fortunate in having obtained so many treasures. I refrain from giving any description of the bones, because Mr. Boyd Dawkins has offered us the benefit of his great experience in these matters. Those who visit the locality will perhaps be fortunate in extending our knowledge of such matters by searching over the whole ground on the flanks of Mam Tor, because from what I have seen during three days' working over the district, I believe this is only one of a number of what we may call "mammalian tombs" which may be found in that district for at least a mile, or two miles. They have never been worked, because the object of all workings is to obtain limestone, spar, or metals. There are many hummocky hills apparently composed of this debris, some of which I have not the slightest hesitation in saying, at some future time, will be found to be great storehouses of bones of extinct animals. I think great credit is due to Mr. Hindshaw, because his instinctive feelings led him to bring away, as something remarkable, what would appear to an ordinary observer to be bone of a horse, or of an ox, which had been killed by falling into a hole, an event of common occurrence on these wild moors.

The Chairman: We are all indebted to Mr. Plant for his communication, which appears to me to be an important one; I do not quite understand whether the bones were found in a fissure in the limestone, or were simply laid upon the limestone, and under the drifted loam, but, from the drawing now exhibited, it appears to be a fissure wholly in the limestone, which has got filled up partially by bones, and subsequently covered by an accumulation of debris. The discovery is more interesting to myself, perhaps, than to any other gentlemen present, for, some years ago, I visited this locality, and made some investigations, and in the clay over a hill—I suppose about half a mile

west of the Blue John mine, the immediate locality referred to by Mr. Plant—I found scattered about a number of massive bones, similar to those upon the table. I examined them, but my knowledge of animal physiology was not sufficient to enable me to determine whether they were fossil bones, or simply the bones of some recent animals which had been buried, and eventually exhumed in the getting of limestone. I have now no doubt, whatever, from the remarks which Mr. Plant has made to-day, that had these bones been collected and examined they would have offered the same degree of interest as these exhibited to-day. At the time, I did not think it worth while to bring them away. I am sure that the gentlemen present will gladly accord to Mr. Plant that hearty vote of thanks to which I am sure he is entitled, for having brought this matter before the Society.

A vote of thanks to Mr. Plant was passed, on the motion of Mr. Boyd Dawkins, seconded by Mr. Forbes.

Mr. Plant: It is undoubtedly a fissure, but one of no great extent, you can put your arms across it easily. It is a surface fissure, and the bones have evidently been washed into it, because they are mixed up so completely with the loose pieces of limestone, and the whole bedded in the loamy debris.

Mr. Boyd Dawkins: Mr. Plant asked me to make a few remarks on this collection, but before I do so, I wish to carry away as clear an idea as I can of the exact conditions of the discovery. First of all with regard to this clay: I believe Mr. Plant has spoken of it as a drift comparable to the drifts in this part of Lancashire; that is to say, a drift more or less connected with the glacial phenomena of this country. I fear, from what he told us of the angularity of the stones—of the fact of there being blocks of limestone, and of these being embedded in clay which was

probably derived from a deposit in the neighbourhood—no real proof exists that this clay is of glacial age, or glacial derivation. I lay emphasis on this point, because it is a point of very great value, as far as relates to this extraordinary collection of bones. From what I can see there is nothing whatever in this deposit to separate it from the superficial deposits in the valley near Castleton, which you will find on the flanks of the valley, pretty well everywhere. When I examined these the other day, in the company of Mr. Prestwich and Mr. Tiddeman, we came to the conclusion that they are not glacial, but the result of sub-aerial wear and tear of the rocks in the neighbourhood. Before I speak of these remains, I wish to mention that in the sub-aerial debris—in the sub-aerial accumulations, rather—some two years ago, Mr. John Tym, the fossil collector, of Castleton, discovered a fragment of a tooth, which I identified as belonging to the woolly rhinoceros. There is evidence therefore, that the woolly rhinoceros lived when the debris was being formed. As far as I know that is the only animal found fossil in those superficial accumulations, with the exception of this very remarkable collection; and I must say it is one of the most astonishing collections of bones I have ever seen in a a deposit of that kind. You often find in such accumulations a scrap of an animal—a bit here and a bit there—but I don't know another like instance of the accumulation of a great mass of remains such as these, in a surface accumulation. With regard to the animals, first I would say that there was originally, at the very least, one whole specimen of a bison. There is a portion of a skull which belonged to an old male bison. There are several horn-cores on the table which belonged also to bisons, of various ages. Some of them are young, and some very old; but from the number of bones which I have been able to examine,—and which Mr. Plant, Mr. Walker, and the other gentlemen have shown me—I

have now no doubt whatever that there was at least one perfect skeleton preserved in that place. There were, I should think, four or six individuals of the bison represented by the fragments which I have seen. Now, besides the bones of the bison, we get certain smaller ones—vertebræ, for instance, which belong to the reindeer; so that we have the reindeer living in that district, at that time. Besides the vertebræ I was able to point out, the other day to Mr. Plant, that we had distinct testimony of the presence of the reindeer, in the fact of these teeth. Besides the teeth and vertebræ, there are a number of smaller bones which indicate the presence of that animal. The third creature which is represented in this collection is the roe deer. Of that we have only one small fragment, but one such as this is quite sufficient to tell us that the roe deer existed in that district. I do not know that I am able to add any other animal to the list.

There is one other point I should like to mention—that is, the presence of a large number of vertebræ. The presence of these vertebræ in that place implies that hyænas did not gain access to the fissure at that time. Had they done so they would have eaten up all these vertebræ, and we should not have found one of them. The general impression left on my mind, after an examination of the remains is that they belong to creatures which happened to die in—possibly they may have crept into this place at a time when it was more open—or at all events that they died somewhere close by, and that their remains become gradually covered up by a sub-aerial accumulation of loam, along with angular blocks of stone. There is one other place in that neighbourhood, where we have discovered the remains of the mammalia of this age—for this group of mammalia belongs to the Pleistocene age,—in a small cave in a dale, about three miles from Castleton,

called Gelly dale. One time, I happened to walk along that ravine with Mr. Rooke Pennington and Mr. J. Tym prospecting for caves—of which there are many in the neighbourhood —and we came to a place where rabbits had been burrowing. On examination we found that they had been good enough to turn out of their burrow, the tooth of a rhinoceros. We explored the cave, and found evidences both of the rhinoceros and the mammoth. Thus, when we look at the whole set of discoveries in that neighbourhood, we have a very fair idea of the animals that once lived there :—we find numbers of bisons, a considerable number of reindeer, a few woolly rhinoceroses, and just a trace of the mammoth.

With regard to the relation of these deposits to glacial period. I am compelled to say that my belief—which is shared by Mr. Prestwich—is, that there is nothing to connect them with the glacial period at all. You have no clear proof that these bones were accumulated before the ice deposits—the clay and the foreign boulders—in this part of the country. Therefore we cannot tell whether these creatures lived in that district, before or after the age which we know as "the great ice age." There is a remarkable dearth of anything you can really call boulder clay, when you get east of the axis separating Lancashire, from that portion of Derbyshire forming the watershed of the upper Derwent. It is only far down the Derwent that you come upon the boulder clay. I believe the glaciers formerly covered that area, but at present we have no certain proof of the fact.

There is one curious circumstance with regard to the drainage of the valley that runs up from Chapel-en-le-Frith towards Castleton—the valley, that is to say, to the immediate south-west of Mam Tor. The drainage which naturally ought to flow steadily westward until it reaches the Atlantic is intercepted to a considerable extent, by swallow holes in the limestone, and thence is conveyed in

a series of subterranean channels through the limestone until it reaches the Speedwell mine, and it comes out in the Peak cavern. So that it is not altogether a fact that all the water westward of Mam Tor flows into the Atlantic through Lancashire. It turns back in this very singular and peculiar course, and ultimately arrives in Derwent, and flows on to join the Trent. I don't know that I have anything more to say, but I am sure I feel personally very grateful indeed to those gentlemen who were enterprising enough to discover this place, and who took the trouble to carry these large bones all the way from Castleton to Chapel-en-le-Frith. As time passes on, all these little scraps of evidence will be put together, and we shall ultimately arrive at a very definite and distinct idea as to the ancient animals which lived in Derbyshire, in the remote Pleistocene age.

Mr. PLANT: In allusion to the term "drift" said, I had no intention to apply that term to the drift in this locality, as it is not comparable to the glacial drifts that we are accustomed to find about Manchester: but my idea of it was, a shaley debris derived from the denuded heights of Mam Tor, as far as the loam was concerned; but that the whole of the embedded angular pieces of limestone were purely local; I have not perceived the slightest indications of any of those travelled pebbles and boulders which belong to the true glacial drift. The drainage in the direction towards Chapel-en-le-Frith is rather difficult to understand. I am not quite certain whether it drains into the watershed of the Mersey. It is very interesting to note that the actual line of waterparting appears to be the point where these bones occur, other details have yet to be worked out, and there are many treasures within this fissure yet to be found. It is important to have made the Reindeer an undoubted denizen, of the Peak district. It is therefore an addition

to our extinct fauna that we may consider to be local. If care be taken in removing the debris, I have no doubt many such as these fine bones, will be found embedded in the stalagmite and amongst the debris which now fills the fissure. I should like to ask Mr. Dawkins whether his attention has been drawn to the broken condition of many of these bones. They are similar in character to the bones which are obtained from the Dordogne caves in France, broken in the same manner and about the same place along their axes. Many of these bones, the smaller ones especially, are undoubtedly fractured by a blow apart from any rubbing or abrasion they would receive in drifting into the fissure.

Mr. Boyd Dawkins: I am afraid I cannot say anything satisfactorily at all about that. I know it is very hard to account for all the fractured shapes of the drifted and cave bones, the one alluded to may have been fractured by the falling of a stone.

The Chairman: I am sure we are very much indebted to Mr. Boyd Dawkins for his instructive address. I have been very much pleased to hear his remarks on the character of the superficial deposits on the eastern slope of the watershed in this particular locality. I have paid some attention to that subject on the borders of Yorkshire and Lancashire, between Bacup and Todmorden, and for some miles north and south of that point; and, it is a fact that no true glacial drift can be detected for a considerable distance from the watershed in that district. There is no true drift until you reach the westerly slope of the Pennine chain, in the neighbourhood of Bacup, rising to an elevation of 1100 or 1200 feet. I was not aware, until I heard from Mr. Dawkins to-day, that the same thing occurred so far south as Castleton. Why true glacial drift should exist at

an elevation of 1100 feet or 1200 feet on the western slope of the Pennine chain, whilst none is traceable on its eastern slope until we are some miles from the summit line of drainage is a problem that has not yet been grappled with by any competent geologist.

I have much pleasure, now, in moving that the thanks of the Society be given to Mr. Boyd Dawkins. The motion was seconded by Mr. WILD and passed.

ADDENDUM.

BY MR. PLANT.

Since the reading of the foregoing communication to the Society, upon the finding of the bones of the Bison and the Reindeer, further examination of the collection then exhibited has led to the identification of bones which belonged to the Bear and to the Wolf, also of bones of a large bird, and of other Pleistocene animals, which add greatly to the interest of the discovery. And in respect to the fact, which was mentioned by Mr. Aitken, of his having seen bones lying about in the vicinity of the limestone quarry near Blue John Mine, I have received several communications from gentlemen who had formerly visited the place, and observed bones lying about, which the quarrymen had evidently thrown out of the fissure, in getting the limestone. These things have been occurring for several years back, but in no instance does there appear to have been any recognition of the fossil character of the bones, or of their geological interest; as the bones looked so fresh, they were considered to belong to horses and oxen of quite modern times, and were thus disregarded by those who found them. I was told by an old man, residing near the Windy Knoll Hill, at Oxlow, that a few years ago, a great quantity of these bones were dug out of

the debris, and carted away to Chapel-en-le-Frith to be ground at a mill for manure, and he thought, that as the quantity of bones was so enormous, that the horses and oxen had been all buried in a hole, after some great plague or murrain amongst the cattle in the Peak district, many centuries ago; in fact, there is a tradition of this kind amongst the people of these high moors, and they look upon every hillock of loam as connected with the mounds and tumuli of Romano-British age, which are found scattered over the high Peak and over Derbyshire generally.

Whatever may be the number of bones which have been turned out of this fissure in years past, and there is evidence to show that the quantity has been astonishingly large; there can be no doubt whatever, that until the discovery of the spot by young Hindshaw at Easter, and by his bringing away a number of the bones, which were identified by myself and Mr. Boyd Dawkins, as bones of the Bison and Reindeer, there existed no scientific knowledge of the real character and interest which attached to the bones as remains of mammalia of the Pleistocene age; and the first announcement of their discovery, to the world of science, has been made through the Manchester Geological Society.

The animals which have at present been identified are the following:—

The Aurochs—*Bison priscus.*

The Cave Bear—*Ursus spelæus.*

The Wolf—*Canis vulpes.*

The Reindeer—*Cervus tarandus.*

The Roedeer—*Cervus capreolus.*

A large bird.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART 5. VOL. XIII. SESSION 1873-4.

At the ORDINARY MEETING of the Members, held at the House of the Literary and Philosophical Society, on Tuesday, June 2nd, 1874. The attendance at the meeting was so small in consequence of the concurrence of the Whitsuntide holiday, that it was decided to adjourn the reading of the Paper announced upon the circular until the next following meeting, at the end of the month,—and at the invitation of Mr. W. Boyd Dawkins, the Council and Members present proceeded to THE OWENS COLLEGE to inspect the arrangement of the collection of fossils and minerals, which the Geological Society had lately presented to THE OWENS COLLEGE. The collection is temporarily placed in a large room on the ground floor, until the new Museum Rooms are built. The specimens have been cleaned and remounted, and are arranged in systematic order, upon the latest classification. It was announced that the room was open and accessible to the members of the Society, for the purposes of study, at such hours in the day during which the College was open to students, in accordance with the terms of the agreement made at the time of the presentation of the collection.

The donations to the Library announced at the Council meeting, included the following books:—

Selwyn, A. R. C. GEOLOGICAL SURVEY OF CANADA, viz., Report of Progress, for 1872-3, imp. 8vo. Report on the Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada, by J. W. Dawson, LL.D., imp. 8vo. List of Publications of the Geological Survey of Canada.

Drown, T. M. Transactions of the American Institute of Mining Engineers, Vol. 1., 1872-3, imp. 8vo, *(From the Council.)*

The Society. Proceedings of the Bristol Naturalists' Society, Parts 1, 2, 1872; and Vol. 1, Part 1, N. S., 1874.

The Society. Quarterly Journal of the London Geological Society, Nos. 117—118; and Abstracts, Nos. 282—287.

The Association. Proceedings of the London Geologists' Association, Vol. 3, No. 5; and Annual Report.

The Society. Proceedings of the Royal Society, Nos. 152, 153.

Mr. JOHN WILD, of Oldham, exhibited a number of iron-clay nodules from coal measures near Oldham, containing specimens of a fossil cone "*Carpolithes Helicteroides*," (Morris,) figured in the Geological Transanctions, 2nd Series, Vol. 5, pl. 38, fig. 12, and described as of rare occurrence in the Coal measures of Coalbrook Dale. This fossil is also found in the "four foot" mine at Bolton, but is nowhere common about Manchester.

At the ORDINARY MEETING of the Members held on Tuesday, June 30th, 1874.

Mr. JOHN KNOWLES, Vice-President, in the Chair.

SUB-WEALDEN EXPLORATION EXTENSION.

A circular was read from the Committee charged with the carrying out of this important work, which was commenced in 1872, to ascertain the thickness of the Secondary Strata in the Wealden area, and the depth and nature of the underlying Palæozoic formations, which there is reason to

believe lie at a depth not exceeding 1500 to 2000 feet at Battle, in Sussex.

A sum of £3000 has been collected by private subscription and spent in this research, and a depth of 1000 feet reached, but as yet without any positive result. The beds traversed belong to the Lower Wealden, Purbeck, Portland series, and Kimmeridge clay, and the boring has now reached the Oxford clay. The Committee make an earnest appeal to the members of this Society for further assistance.

Donations to the Library from Mr. J. G. Lynde, F.G.S., were announced, being a copy of the Report of the Geological Survey of Canada, &c., by A. R. C. Selwyn; and from Professor E. Hull, F.R.S., his work on "The Building and Ornamental Stones of Great Britain and Foreign Countries," 8vo, 1872.

Mr. John Aitken, F.G.S., read the following paper:—

ON THE OCCURRENCE OF HIGH LEVEL DRIFT IN THE NEIGHBOURHOOD OF BACUP.

By Mr. John Aitken, F.G.S.

In February, 1868, I drew the attention of the Society to an outlier of drift, situated on the top of Holcombe Hill, at an elevation of 1150 feet, and described the character of the pebbles found therein, one of which upon investigation turned out to be a true flint.* More recently, I exhibited a number of drift pebbles, amongst which was one of flint from a patch of drift discovered on Horncliffe Moor, at an elevation of 1060 feet.† Since then I have succeeded in obtaining undoubted evidence of the existence of foreign stones on some of the higher hills in the neighbourhood of

* Trans. Man. Geo. Soc., Vol. VII., p. 80. † Ib., Vol. XII, p. 42.

Bacup, at even higher elevations than the two instances already cited. The first locality to which I wish to direct attention is that of Brandwood Moor, which comprises a lateral spur of land thrown off in a westerly direction from the main north and south range of the Pennine hills, and which, combined with its western prolongation, forms the line of separation between the hydrographical basins of the rivers Irwell and Roach; the height of which is about 1250 feet. On the summit of this hill I have found Silurian grits, Syenite, and Quartzite boulders in moderate abundance, intermixed with angular pieces of gritstone and blocks of gannister, the whole embedded in a matrix of coarse sand derived from the disintegrated rough rock upon which the layer reposes, the whole covered over by a surface bed of peat varying from one foot to seven feet in thickness. The Silurian grit is of the usual character to that found so abundantly in the drift of Lancashire. The Syenite is of a fine grained compact variety, of a pale pink colour having small specks of hornblende freely distributed through the mass, these together with the felstone are probably derived from rocks of this character, which exist in the Lake district. Brandwood Moor consists of a narrow neck of land of somewhat lower elevation than that to the east or west, at the eastern extremity of which a narrow valley has been cut separating it from the more elevated region further to the east, through this gorge and also over Brandwood Moor, a body of ice undoubtedly passed during the glacial period, its smoothly rounded contour, and the large accumulations of drift in the Cown and Shawforth valleys immediately to the south, charged with boulders and pebbles identical with those left on the hill above, bear testimony to this fact and prove that this was the highway of at least one branch of the great stream of ice which at one time moved over the county of Lancaster.

The next locality is that of Bull Hill, the highest point on the ridge of land of which Holcombe Hill forms the southern and terminal promonotory, and from which it is distant about one and a half miles in a northerly direction, the height being 1371 feet. Upon the summit of this hill I found lying exposed upon the surface a number of pieces of volcanic ash,—one an angular block of moderate size, Silurian grit, and Quartzite grit very fine and compact in texture, weathering white on the surface upon exposure to the atmosphere, white and pink quartz, an agate, and two pieces of flint. The rock specimens with the exception of the quartzite and flints have evidently been brought here from the north, rocks of similar character being found in *situ* in the Lake district. I have procured agate identical with the specimen produced from a section near Ireleth, in Furness. I am, however, unable to assign a locality for the grit, no rock like it occurs in Lancashire, nor so far as I know anywhere in the mountainous districts of the north.

The two flints present features which render it exceedingly probable that they ought correctly to be assigned to pre-historic rather than glacial times, the larger specimen has undoubtedly been chipped by artificial means and fashioned into its present form for some useful purpose. The smaller piece also bears evidence of design, having been struck off from a larger mass by the hand of man, and is what is generally recognised as a flint flake, both pieces bear evidence of great antiquity, the fractured surfaces presenting that dull lustreless appearance which characterise true neolithic flints, they are much lighter in colour than any of the flints I have previously found in the drift of this neighbourhood. These specimens then assuming their artificial character are of considerable interest, carrying back the occupation of this part of the country by man to

pre-historic times, this being the first evidence, so far as I am aware, of the presence of the human race at this early period of the earth's history in this portion of East Lancashire. It will be noticed that the larger example is somewhat incomplete, having apparently had the point broken off subsequently to its being formed into an implement of war or the chase.

The surface of the hill upon which these stones were found presents a bleak wild aspect, being destitute of vegetation and covered over for some distance by large numbers of sharp angular stones consisting of a fine yellow free grit intermixed more sparingly with rounded pebbles of various sorts, as already described, the quartzite grit being the most abundant next to the grit-rock. The bleak character of this area arises from the practice which has been in vogue for generations past of removing the peat for use as fuel, thus exposing the lower and less fibrous part to the wasting action of the atmosphere, by which means it has ultimately been entirely removed, leaving the subjacent stony layer exposed on the surface.

The third instance to which I would refer occurs on the summit of Cribden, a bold boss of land overlooking the valley of the Irwell at Rawtenstall, where, at an elevation of 1300 feet, I picked up a small volcanic ash boulder much weathered by exposure, the outer portion being quite decomposed. As yet I have not had an opportunity of fully investigating this area, but have strong reasons for believing that confirmatory evidence might be obtained of the existence of other drift materials on this elevated and exposed situation. On the same hill, a short distance to the north, I have noticed the occurrence of white compact quartzite pebbles foreign to the district, and I have also observed numerous small pieces of dark coloured chert along the hillside at an elevation little less than that last named. At the

top of Ousil Clough, near Crawshawbooth, where the stream takes its rise, on the moorland between Cribden and Hambleton I found, at an elevation of about 1100 feet, a fine suite of drift pebbles, comprising Silurian grit, quartz, quartzite, syenite, pink granite, gneiss, porphyritic greenstone, felstone, and limestone, together with others not so easy of identification. I also found gneiss, felstone, and Silurian grit near the source of Gin Clough, a little further to the north than the last-named locality, and at about the same altitude. The surface at the elevation named became, in the two last instances, covered by a layer of peat, thus effectually preventing the examination being continued to a greater height. From these facts I deem it highly probable that the single boulder found on Cribden may indicate the presence of drift on that eminence in greater quantity than yet determined. I have also in my possession a small boulder procured from near the summit of Dirpley Hill,* at an altitude of about 1370 feet. This was brought to light by the occurrence of a landslip which took place during a wet season about two years ago. The boulder has been determined by Mr. D. Mackintosh, who has devoted special attention to the Lancashire drifts, as a piece of felstone, and he states that rock of this character is found in the Lake district.

A bed of drift gravel also exists at Higher Stack, about a mile south-east of Bacup, at a spot marked gravel pit on the Ordnance map, full of foreign pebbles of considerable variety, at an elevation of 1110 feet.

Other examples might be given were it desirable to multiply instances showing the presence of drift at considerable elevations in this part of East Lancashire, but sufficient has been done to confirm the assumption of a body of ice of immense thickness having at one time flowed over

* Dirpley Hill is 1429 feet high.

the country, rising up to the level, if not entirely submerging, the higher eminences in the neighbourhood of Bacup. These facts lend support to the theory so admirably propounded and enforced by Mr. R. H. Tiddeman in a paper lately read before the Geological Society of London,* whereby he has shown that the ice proceeding from the Pennine chain during the glacial period was shouldered up by the lateral pressure exerted by the more important flow of ice further to the west from the Lake district, and by this means compelled to pursue a course over hill and valley at nearly right angles to the natural drainage of the land, and to the direction in which it would consequently, if not interfered with, naturally have flowed by the simple law of gravitation. Although fully endorsing the views advocated by Mr. Tiddeman with much force, I am inclined to think, from the evidence of the drift in this part of Lancashire, that the flow of ice after rounding the southerly end of Central Fells, in the Lake district, took a somewhat more easterly direction than that indicated, and that the Lake district ice impinged upon the main body of the Pennine range somewhere in the neighbourhood of Burnley, and thence flowed almost south along the westerly side of those hills, crossing in its course the lateral spurs thrown off to the west, finally debouching on the wide expanse of the Cheshire plain.

The presence of flint pebbles amongst these high level drifts so far north of the cretaceous formations of our island present difficulties not easily explained. They may, however, possibly have found their way over, by the agency of ice, from the north of Ireland, or they may have been drifted from the chalk districts in the south during the period of submergence of the land on the occurrence of one of those warm periods which, upon the authority of Mr. Geikie,

* Q. J. Geo. Soc., vol. 28, p. 471.

occurred at intervals in the glacial epoch, and when perhaps a southerly current had temporarily set in, mitigating to some extent the terrors of that protracted winter.

Mr. Knowles: The subject of the paper we have just heard is one of considerable interest to the members, and will form a valuable addition to the information already given by Mr. Aitken of the special features of the drifts in the higher parts of Lancashire. Doubtless these peculiar boulders and flint pebbles will assist the geologists to proper conclusions when the whole question of the drift formation is better understood.

Mr. Plant: It is almost impossible at the present day for any geologist to be sceptical upon the theory of the great ice sheet having once overspread Lancashire. The subject has received so much attention at the hands of several eminent observers, including Professor Ramsay, Professor Hull, Mr. Green, Mr Tiddiman, Mr. Clifton Ward, Mr. Brockbank, and Mr. Mackintosh, whose memoirs upon the glaciation of the Lake districts and North Lancashire are so ably written and extensively illustrated by maps, showing in a marvellously minute way how the whole of the Pennine hills are scored with ice marks of different kinds, and the valleys and moors more or less deeply covered with the drift deposits left by the ice and waters of the glacial period. Amongst the local geologists who have rendered good service in searching for evidence of these phenomena within his own district, those from Mr. Aitken will bear a high position, and the present paper adds considerably to our knowledge of the highest deposits of drift, and consequently the oldest, we have in the Manchester district. I believe it is the first instance recorded of boulders from the volcanic ash beds of the north being

found in the local drift, and as far as I can judge by comparison they resemble the volcanic rocks which I have seen intercalated in the Lingula slates a few miles north of Dolgelly. They are sufficiently hard to sustain the wearing of glaciers into boulders. The specimen which Mr. Mackintosh has named as a felstone seems to me to be more likely to be a chert, boulders of which are occasionally found in the drifts coming from the north, probably from the limestone of Clitheroe; it has all the splintering fracture of chert, and lacks the peculiar glistening surface so characteristic of felstone. However, I admit that Mr. Mackintosh is a good authority for the characters of the specimen, if it comes from a rock which he has observed in *situ* in the Lake districts. The boulders exhibited by Mr. Aitken differ in their characters from the bulk of the boulders found in the valley drifts of Lancashire, and especially is this the case when flint pebbles are found mingled with the usual boulders from palæozoic rocks. These flints are of true cretaceous age, as has been proved by the *foraminifera* found in them, and the only unobjectionable suggestion to account for them is the one, that they have come from the chalk formation in the North of Ireland; but with respect to the two chipped flints exhibited, there need be no hesitation in saying that they are shaped by the hand of man, as they are identical in shape with the broken flint-flakes from the cave floors of Les Eyzies, and quite agree with similar broken flints found in surface soils in Yorkshire, and with some I have found on the high moors near Castleton, a good number of which I now exhibit. These are all of modern age, when compared with the boulders from the glacial drifts. I have to move the thanks of the members to Mr. Aitken for his paper.

Mr. Kay Knowles: I have much pleasure in seconding

the motion for a vote of thanks, and to express the interest I have felt in listening to the paper from Mr. Aitken.

Mr. AITKEN acknowledged the compliment, and remarked that with regard to the chipped flints on the table, Mr. Plant would notice that I described the specimens exhibited as worked flints. The remarks, towards the close of the paper, about flint pebbles having been drifted into the neighbourhood, had reference to some which I found on other moorlands, and previously exhibited here. They were quite different in character from the two worked flints laid on the table to-day. The former were true rounded pebbles, similar to any other pebbles that may be taken out of glacial gravels, and totally different both in colour and form from these, which have been artificially shaped. With regard to the felstone specimen, Mr. Mackintosh, to whom I sent it, pronounced it to be felstone; and he says rocks like this are found in *situ* in several localities in the Lake district.*

Mr. PLANT then read the following paper :—

ON THE OCCURRENCE OF QUARTZITE BOULDERS AND PEBBLES EMBEDDED IN TRUE COAL.

BY MR. J. PLANT, F.G.S.

It has long been known as one of the least understood features belonging to the formation of layers of shale and coal, that rounded nodules of widely different mineral matter are found embedded in them. The most numerous of these nodules occur in some of the lower coals, and are known locally as "bullions," having a good deal of iron pyrites held in a matrix of fine carbonaceous shale, together with fossil shells such as *Goniatites*, all rolled up into a

* Since this paper was read, Mr. Aitken has been fortunate enough to find, on Bull Hill, several perfectly formed flint-flakes and arrow-heads, with a flint core and numbers of flint chippings—they all lay at the bottom of the peat deposit.

ball, which appears to have been indurated at the time of its deposition in the shale. Others appear to have been formed by the rolling of masses of an adhesive fine iron clay around a fossil nucleus, either a shell, or a fish, or, more generally, the long fruit-like cones of the Lepidodendron or other of the coal plants. These are usually oblong flattened nodules, and occur in great numbers in some of the shales of the middle coal measures. Of these nodules there does not appear to be any difficulty in ascribing their formation to the action of moving water, gently rolling the embedded objects and the fossils about until they become completely enwrapped in the muddy and ferruginous clays that formed the beds of the lakes or rivers of the coal period, as the shales, coals, nodules, and fossils are undoubtedly all contemporaneous.

In the sandstones, flags, and grits of the coal measures, from the lower to the higher beds, nodules are met with like hardened balls of sand, or of ironstone, lying cleanly embedded in the hard strata of the sandstone; the nodules rarely differ in texture from the matrix they are found in, and when there is any difference to be seen, it arises from an apparent coating of peroxide of iron, or from the nodule being made by concentric layers of sand largely mixed with peroxide of iron. These nodules are of moderate size, generally about the size of a cricket ball, but a few will attain to bulk of almost six inches diameter. The origin of these nodules is not so satisfactory explained as are those first mentioned, for, although they are usually globular in form, there are doubts in referring them all to the action of rolling by the movement of the water, and in no instance that I have seen do they begin their concretion by a fossil nucleus. I deem them to be rather the result of the agglutination of sand and mud by the decomposition or oxidation of a particle of iron from a central point, and the

size of the completed nodule depending upon the quantity of iron oxidized. Whatever may be their origin, there can be no doubt upon one point, that is, that they are similar in mineral matter, and are contemporaneous in formation with the sandstones in which they are found.

The Boulders and Pebbles, which are found exclusively in the beds of pure coal, are altogether unlike those which are found in the shales and sandstones, and the manner of their occurrence is so singular as to invest them with an interest to the geologist fully equal to that which he finds in restoring the forms of the extinct reptiles, fishes, and plants of this prolific epoch in the history of the earth. In the Roger Mine at Dukinfield, at a depth of 400 yards, a good number of these boulders have been found by Mr. William Seddon, to whom I am indebted for several specimens, and for information of their position within the bed of coal. Other specimens have been shown me as coming from the coal beds at Pendlebury, and Mr. T. L. Woodward has supplied me with the details of the finding a group of about twelve in the Two-Feet Trencherbone Mine, Spindle Point, Kersley.

SECTION OF THE TRENCHERBONE MINE,
AT SPINDLE POINT.

	426 yards from the surface.
Coal.....	3 feet 6 inches.
Shale	$1\frac{3}{4}$ inch.
Coal.....	2 feet 3 inches, containing about 20 boulders in a group.
Floor	

These boulders are reported by the miners to be of rare occurrence in the coal beds, and it is certain that they seldom are found in the *coal box*, but when they do occur, it is in groups of five, six, a dozen, or even twenty, all lying in a limited space, but separately embedded in the coal. They are of varying size, ranging from a small marble to three feet in circumference, and although smoothed, and even polished on the surface, are not always globular; some of the large ones are ovoid in shape, some cuboid, with the corners entirely worn away and smoothed. Many of the pebbles vary in their shape, as do the pebbles that are gathered on a shingly beach. When they are first extracted from the coal, they are covered with a tightly adhering skin of carbonaceous shale, which clings to and follows every wrinkle and hollow on the surface; sometimes this skin is studded over with fragments of the teeth and scales of fishes, but usually it is bright and smooth.

The largest boulders are as heavy and compact as is the basalt of the Giant Causeway; in fact, the first aspect of a large nodule is that of a boulder of trap, similar to those which are so frequently found in the boulder clays, and on being broken, the character of the fractured surface assimilates also to that of a fine close-grained trap. This appearance, however, is deceptive, as I have not met with any of these boulders of large size that are not quartzites, and apparently all derived from one parent rock,—a fine-grained, gray reddish-gray or darkish gray quartzite,—with a specific gravity equal to that of the heaviest basalt. When a fragment is examined under the lens, the composition is identical with certain metamorphic quartzites that occur in the Cambrian rocks in North Wales.

It is clearly to be seen that these boulders were originally derived from one common source, that is, a parent rock of fine-grained sandstone, in which, by metamorphic heat, the

grains had been partially fused into a semi-crystalline siliceous cement, and much indurated by pressure.

The pebbles of small size are most frequently composed of a semi-crystalline quartzite, somewhat simulating the characters of a rock crystal, but in no case purely transparent, prismatic, or with a conchoidal fracture. One specimen—a rough cube of about two inches, but with the surface permanently blackened and smoothed, as is the case with all I have seen—is a greenish quartzite, very much resembling the common *vein-quartz*, which occurs in the gold districts of North Wales, and another small cubical pebble is evidently derived originally from a white fatty-opaque quartz vein. In one pebble of extremely fine dark quartzite, very much resembling some samples of Welsh aluminous slates, I have detected a minute black glistening scale, but whether it is a scale of mica, or of organic character, is uncertain.

To account for the occurrence of these quartzite boulders and pebbles in the *Coal-beds alone*—for I have not as yet heard of the finding of any similar boulders in the shales, or in the sandstones of the coal measures—is a question that is not readily nor satisfactorily answered. There will be no question to the assertion that they have all been derived from rocks, older than the Coal measures, the Yoredale shales, or the Old Red Sandstones—for quartzites of this nature are not known to belong to the strata of any of these formations in Great Britain. They may possibly be derived from the Middle or Lower Silurian, or even of Upper Cambrian strata, in which metamorphic quartzites are occasionally intercalated, but, in my opinion, founded upon observations made in Merionethshire and Anglesey, I deem it to be most probable that they were derived from the mountains of the Old Cambrian continent which must have existed during the long periods of the deposition of the Carboniferous formation, or, at least, of that upper portion

of this formation which embraces the age of the true coal-bearing beds.

It is the present belief of our leading geologists that a great Palæozoic basis underlies all the formations later than the Silurian, and that it does not lie so deep in the eastern part of England but that it can be reached by the boring rod; and it is one of the best understood laws in physical geology that the older formations have been extensively denuded to find a large portion of the materials for the accumulation of mineral matter for newer formations, and that in all geological periods, the sea, the rain, and atmospheric agencies have abraded and dispersed the materials of the land and re-spread them on the bottoms of seas and lakes. There can be no objection to the suggestion that these smaller pebbles have been borne amongst the matted roots of the carboniferous trees when they fell and were floated to the place where they became embedded and changed into coal. This would be only a natural and ordinary occurrence, one such as can be seen in action in the present day, when great trees are torn up and carried away by a flood, the roots holding, for a long time, great quantities of gravel and clay as they float upon the water, but in respect to the largest boulders, such an explanation is not sufficient to account for all that has been observed upon them.

If it were allowed to ascribe their peculiar shapes, their smooth, polished and strangely moulded and scored surface-markings to the action of *glacier* motion, as is the case with similar boulders found in the drifts and till clay of the last Glacier period, their presence in the coal would be perhaps satisfactorily accounted for; but it has not yet been advanced as an hypothesis, that the climate of the middle carboniferous period would allow of the existence of glaciers, whose range could extend so low from the high mountainous

regions as to be able to deposit the ice-borne boulders in the rivers and lakes of the warm regions, where the mighty Lepidodendron and its congeners would grow The only possibility of connecting their origin with the action of glaciers will be in suggesting that they were probably glacial boulders of a much older epoch—the Silurian or Devonian; and had been deposited in the deep drifts, which covered the great plains of the Carboniferous lands, which from time to time were denuded by floods, and the washed-out boulders re-deposited in the carbonaceous matter at the bottoms of the rivers and lagoons.

There is one other suggestion of great probability to account for their presence in the coal, and that is, that they were boulders from the sea beaches of the Carboniferous seas, which by some agency had been carried out to places where masses of vegetation were accumulating and being converted into coal. But there are several objections to this view, in the shapes of the boulders not being like *rolled* beach stones; and in the want of any known agency to effect their transport in small groups of five, ten, or twenty boulders directly into the forming coal bed, in a quiet still inland sea, such as was necessary for the depositions of the vegetation to form a bed of coal.

My conclusion is, that we may regard them as boulders of glacial origin, shaped and scored by glaciers that existed during the middle palæozoic periods, and that they were torn away from the peaks of the old Cambrian rocks—of which we have fragments yet existing in North Wales, in Merionethshire, and at Holyhead—and embedded in the glacial *debris* and drifts, overspreading the valleys and plains, that existed when the coal beds were being formed, and that their presence in the coal beds can be accounted for, by ascribing them to the denudations of these old

glacial drifts by the streams and rivers of the Carboniferous period.

The CHAIRMAN said that Mr. Plant's paper was a most interesting one. The question had occurred to him whether the stones referred to had not been, at some time, washed up by the sea; but the objection to that was, that they were found only in small numbers. As far as could be seen, it would take some time to discover whether Mr. Plant's theory was a correct one, and it could only be by members of the Society bringing forward other instances of their being found in the coal mines, and so accumulating information which might lead to definite results. There seemed some probability in the supposition that the boulders had been deposited by glacial agency; but that glacial action should have occurred at a period when there was, presumably, a hot climate—when the tropical plants grew which were the origin of coal—was hardly reconcilable with known facts.

Mr. MARTIN asked whether the boulders referred to were similar in character to those found near Bacup and Todmorden, and which were laid out in large numbers on the sides of the tram roads, he had noticed that such boulders were liable to disintegration, by the action of the weather, especially during winter.

Mr. AITKEN: The nodules to which Mr. Martin has alluded are of two classes in that particular district, and have been taken from the beds of coal shales. They are composed almost entirely of organic remains; and from these nodular concretions some of the best stems, representing the vegetation of the coal period, have been obtained by Mr. Binney, Professor Williamson, and others, who have paid attention to fossil botany. There are others which are

derived from the clay shales overlying the coal, and which do not contain vegetable matter, or, at all events, only in very small quantities. These seem to contain a nucleus—formed of Goniatites, or the Ceratites, &c.—peculiar to Lancashire, and are altogether different from the boulders described by Mr. Plant. I may call special attention to two or three similar boulders which I procured from the gannister coal bed, including a fragment of a large boulder from the neighbourhood of Bacup. I secured this large specimen from a collier soon after he had taken it from the coal. It is a quartzite, very peculiar in character, and at the time I got it was perfectly white, the coal still adhering to its surface, in places, affords indubitable evidence that it was taken from a coal bed. I am glad Mr. Plant has brought before us so plausible a theory as the one propounded. It has always been, to me, a difficulty how to account for the presence of these siliceous boulders. I have known of their existence in the coal for many years, and have had several specimens in my possession, and seen others which were in the Geological Society's Museum, and there was a very considerable number—some of them larger than these—which had been brought, I believe, from the neighbourhood of Bolton or Wigan. The only way in which I can account for their finding their way into the coal is the one suggested by Mr. Plant, it is the one which, to my mind, has the greatest probability of truth. It has been suggested by some speculating theorists that these boulders were bombs thrown out from the volcanoes of the moon, and, being attracted by the earth, fell into the coal during its deposition. We are hardly prepared to accept such an unsound theory. Mr. Plant's idea of a glacial period during the Cambrian epoch is to me perfectly new, it is ingenious, and does, at any

rate, offer an explanation of the existence of these boulders at the time of the coal formation.

Mr. JOHN WILD, referring to some pebbles which he had brought to the meeting, said that they were taken from the roof of the Arley mine, the largest and most angular piece was coated on both sides with fish remains and vegetable matter; and that being the case—the shale being very fine—he could scarcely agree with Mr. Plant's theory with respect to glacial action. He had not found marks of glaciers in the measures overlying the Arley mine. His impression was, from the abundance of fish remains near them, that the smaller pebbles had been in the stomachs of fishes, and were deposited, with other matters, in the coal beds when they were being formed.

Mr. PLANT: I have not advanced the theory that glaciers existed *during the formation of the coal*, and I am quite opposed to it. My theory is, that glaciers existed in the Palæozoic epoch, and that these are boulders which were deposited in enormous sheets of drift forming the swampy plains of the Carboniferous continent, where the forests of coal trees were growing. The action of moving waters, and of rivers especially, is to eat out the land and redistribute the material. I have supposed that these boulders have been washed out of the Cambrian drift, and re-bedded in the quiet seas and waters where the coal was being formed. I cannot conceive the possibility of glaciers existing contemporaneously with the formation of coal. Mr. Wild's suggestion with reference to these smaller pebbles is one that is based upon the knowledge that birds will swallow pebbles to aid in the trituration of their food, and that these pebbles, for a similar purpose, may have been swallowed by fishes, I was not aware, however, that fishes require such aids to digestion. The large specimen brought by

Mr. Aitken is one of the most convincing proofs that these boulders and pebbles are of Cambrian age, had this specimen been cleared of its carbonaceous skin, and simply shown to me as a specimen of quartzite, I should have had no hesitation in deciding that it came from North Wales, as I have seen hand specimens of a quartzite very similar from one or two places in the neighbourhoods of Trawsfynydd and Harlech.

REMARKS ON THE BONE CAVE OF WINDY KNOLL, NEAR CASTLETON, RECENTLY DESCRIBED BY MR. PLANT.

By Mr. John Aitken, F.G.S.

At the meeting of this Society, held on the 28th of April last, Mr. Plant announced the discovery of an ossiferous fissure in the limestone at Windy Knoll Quarry, near Castleton, Derbyshire, and Mr. Boyd Dawkins at the same time gave a description of a large number of the bones which had been found in the fissure. Since then I have visited the place, and I find that the supposition I ventured to express at the meeting, as to its being identical with that where some five or six years ago I saw a considerable number of large bones thrown together in a heap at one side of the quarry, is fully borne out, although, as I stated at the time, I failed to make out their true character or scientific value, looking upon them merely as the bones of domesticated animals.

Upon a consideration of all the facts of the case as detailed by Mr. Plant, and after an examination of the features on the spot, I have come to a conclusion somewhat at variance to that arrived at by him as to the character of the fissure in which the bones have been found so abundantly.

Mr. Plant described it as an open fissure, which he supposed had been filled in from the surface subsequent to the entombment of the bones. The difficulties which presented themselves in adopting that explanation, when taking into consideration the occurrence of so large a number of bones, representing so varied a fauna, mingled together in a space so limited, some of which belonged to carnivorous animals, and of which so large a proportion were in a broken and fragmentary condition, raised doubts in my mind as to the possibility of reconciling these facts with the supposition of their having occupied an open surface fissure. I therefore not only directed my attention to an examination of the place of sepulture, but also instituted inquiries as to its original character and the conditions under which the bones have been found at former periods, and I have been led to conclude that the site, when first discovered, was a true cavern, and not merely a fissure excavated into the surface of the rock, and that, during the operation of mining, the miners came in contact with it near its furthest extremity, some six or eight yards from the entrance, where it presented the appearance of a blocked-up subterranean channel, in the matrix of which large numbers of bones were found embedded. In carrying on the works of the quarry, it was at intervals gradually worked back from the extremity towards the entrance, each operation revealing a quantity of bones, the last of which took place as described by Mr. Plant, at which spot the face of the rock having been reached, and the roof ceasing to exist, the cavern was changed for a short distance before finally disappearing into an open surface channel, bounded on each side by masses of rock. The exact spot, therefore, examined and described by Mr. Plant, I consider to be the mouth of the former cave, at which place it appears a large accumulation of bones took place. The

stones which form the sides of the entrance to the cavern terminate the rock in this direction, the local surface drift accumulations at that point taking its place. If, then, I am right in the hypothesis that the mouth of the cave has been reached, the place must be considered as worked out; and that no further discoveries of bones to any extent can again, in all probability, take place; of its correctness further research will determine. The entrance to the cave is at the foot of, and directly opposite to Mam Tor; and it appears that the disintegrated matter from that elevated moor land, in conjunction with the limestone of the immediate locality, has furnished material by which the cavern was eventually blocked up. It is, however, worthy of note that the line of fault which crosses the country from east to west, by which the limestone of the south is brought up against the Yoredale rocks of Mam Tor, passes close by the quarry, the termination of the rock at the mouth of the cave probably forming the southerly boundary of the fault at that place.

I may add that these remarks have not been called forth by any feeling of captiousness, but solely from the desire of placing before the Society the facts of the case as they presented themselves to my mind, after an examination of the whole of the evidence which I have been able to collect bearing upon the subject. In all other respects than that of the character of the ossiferous channel, it affords me pleasure in bearing testimony to the accuracy of the description given by Mr. Plant, and to fully recognise the value of his communication.

Mr. Plant: The communication which has now been made upon the subject of the great "find" of bones near Castleton, gives me an opportunity of making a few

observations upon some further specimens of the bones which we have lately acquired from Castleton. The fissure has at present yielded only the remains of animals which are extinct in Great Britain, although, as in the case of the aurochs, the reindeer, the bear, and the wolf, they are yet living in some places on the continent. The specimens on the table include a well-preserved hind part of the cranium of a reindeer, and the hind part of the skull of a bear, which probably belonged to the grizzly or to the brown bear. The sacrum of another bear, which I have satisfactorily proved to be that of the cave bear, (*Ursus spelæus*) placed side by side with similar bones from the Grotte des Echelle in France, it agrees to the most minute characters with them, and I do not hesitate to maintain that it is a bone of the true cave bear. I associate with this sacrum, another vertebra and two fine upper canine teeth, as belonging also to the cave bear. The wolf is represented by a portion of the end of a lower right jaw containing an incisor tooth in perfection, and by a remarkably perfect sectorial molar, probably belonging to the same portion of jaw. There are also evidences of the wolf amongst the femoral and humeral bones in the collection. We have now collected sufficient evidences to prove the contemporaneous existence, in Pleistocene times on the moors of the High Peak, of the Bison or Aurochs, the Reindeer, the Cave Bear, the grizzly or Brown Bear, and the Wolf.

The only regret we must all feel upon the question is, that there once existed a fine opportunity of making a grand collection of the remains of these, and perhaps of other Pleistocene mammalia, but that, through the ignorance of the quarrymen and the culpability of others residing at Castleton, who professed to have some interest in geology, and claim to have had a knowledge, that these bones were

being turned out of the fissure for several years past, they were so far neglected as to lie about in heaps, until they could be conveniently sent to a bone mill and sold for making bone manure, we hear of cart loads being so disposed of during the last three years, and science would never have heard of this rich ossiferous fissure had it not been for the accidental discovery of the bones, in April last, by the young geologists from Manchester. Many Museums in England would have been glad to have been enriched by a few of the thousands of bones that have been destroyed, and I regret personally to say that, for the part I have taken in making the discovery of the bones known to the world of science, I have been most liberally abused by these people at Castleton, ever since they were taught that the bones they had so long neglected, belonged to something more interesting than the oxen and horses they ignorantly took them for.

When I visited the quarry the appearance of the place in which the bones were embedded never suggested to my mind that it had been a cave, and I carefully avoided using the word cave, but I am quite ready to agree to the suggestion now made by Mr. Aitken, that before the ground was disturbed by the quarrymen there most probably existed a small cavern, which has been almost worked out, and the floor fully exposed to daylight.

In connection with this subject I wish to refer to the six specimens of chipped flints on the table, which I found on the high moors near Castleton, they are similar to the two chipped flints which have been described by Mr. Aitken in his paper. I do not care to mention the exact locality where these came from, as I may be again called hard names if I let out the secret to the Castleton geologists. The flints are, beyond all questions, pre-historic weapons of the flint-flake

character, not fine ones, it is true, but sufficiently good to be compared with hundreds of such flakes that are found in Yorkshire and elsewhere. I have no doubt the locality where these came from has great numbers upon it, and probably, as we are only now beginning to be acquainted with existence of pre-historic relics in the surface soils of this district, the finding of such specimens will be in time very common, every fresh find will add to our knowledge of the strange changes in climate, the animals and plants and also of man, which time has witnessed over in the high moors of Lancashire, Derbyshire, and Cheshire.

The following specimens were exhibited:—

Boulders of granite, greenstone, volcanic ash, Silurian grits, flint pebbles, and other rocks, from the drifts over the moors; two worked flint-flakes from the bottom of the peat deposit on Bull Hill, in illustration of the paper by Mr. Aitken; a number of quartzite boulders from the coal beds, exhibited by Mr. Plant, Mr. J. Wild, and Mr. Aitken; a number of specimens of bones, including a *sacrum*, *vertebræ*, and two *canine teeth*, of *Ursus spelæus*, a *jaw* of a wolf, part of the *crania* of the brown bear, and of the reindeer, exhibited by Mr. Plant in illustration of his remarks on the Castleton deposit of extinct mammalia; and six worked flints of the "flake" and "scraper" types, which came from the neighbourhood of Castleton, being found on the surface of the high moors.

TRAN. MAN: GEO: SOC: VOL. XIII P. 107

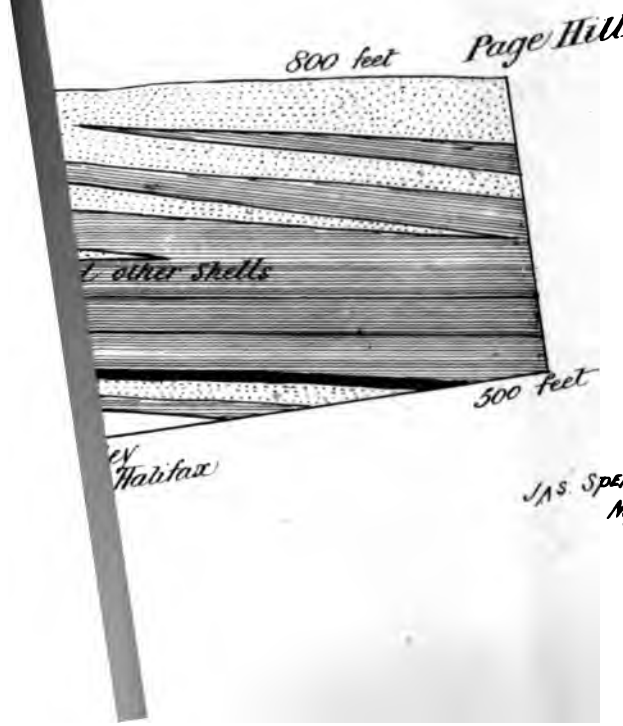
DCK.

he eastern Edge of

E - Vertical. 1 inch = 100 foot
Horizontal 1 foot - one mile

S

- Measure hills 1 mile to the East



JAS. SPENCER.
MARCH 26. 1874.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART VI. VOL. XIII. SESSION 1874-5.

ANNUAL MEETING.

The ANNUAL MEETING of the members of the Society was held on Tuesday, the 27th October, in the Philosophical Society's Rooms, George-street, Manchester.

The President, Mr. THOMAS KNOWLES, M.P., Wigan, occupied the chair, and there was a very fair attendance. The notice convening the meeting having been read,

Mr. J. E. FORBES, F.G.S., one of the Hon. Secretaries, read the Report for the past year.

REPORT.

It is with feelings of satisfaction that your Council find themselves able to report most favourably of the affairs of the Society, their anticipations that an improvement would be effected by holding their meetings at the rooms of the Literary and Philosophical Society have been fully realised, and the members who have been present at the meetings must have all felt this very agreeable change in their convenience and comfort.

During the session which has closed seven ordinary meetings have been held, and a perceptible increase in the attendances has been observed; the average attendances of members and visitors has been 24 at each meeting.

The members will be their own judges as to the scientific importance of the papers which have appeared in the printed Transactions during the session, but the Council may be permitted to remark that in all instances the subjects of the papers have been interesting, whilst some of them have announced new discoveries in Geology in this locality, and in this respect are important in being contributions which add new features to our knowledge of the specialities of the Geology of Lancashire and the bordering counties.

The Council would direct the attention of those of the members of the Society, who are directly engaged in coal-mining and mining generally, to one paper on Coal-cutting Machinery as an instructive one; it is the only contribution during the session upon mining matters, and they would press upon those members that they would be doing an essential service to the Society by contributing papers of a similar character either upon the economic management of mines, explosions in mines, or other important features which belong to mining. Many highly estimated papers upon these subjects will be found in the earlier volumes of the Society's Transactions, and it is desirable that these should be continued so as to be a permanent record of the improvements and changes which yearly are being effected in all mining appliances and management.

The Society at the present time has enrolled 120 members, of which 91 are subscribing members, 8 are life members, and 21 honorary members, 12 of whom have been elected during the present session. The Council have much regret to record the decease of three distinguished men, who have been members of this Society from the year of its foundation in 1838; their loss to the Society leaves a blank which will never be filled in like degree. Louis

Agassiz, Professor John Phillips, Sir William Fairbairn, are names universally honoured. Four other members are also deceased—Mark Philips, Peter Higson, sen.; William Brooke, F.G.S., and D. S. Clayton.

Two new subscribing members have been elected during the session.

Your Council have had under their consideration the rules as they were framed at the time of the amalgamation of this Society with the late Natural History Society, in 1851. Many of these rules were no longer applicable to the present governance of the Society. The Council now submit to the members an amended code of rules, which have been carefully considered, and which, they trust, will meet with approval.

The Society has been favoured by a large increase in the donations of works upon Geology and Mining from their authors and from kindred Societies, both in Great Britain and abroad, especially from the Geological Surveys of the United States and Canada. These additions are of considerable value, both in a pecuniary and in a scientific sense, and tend to make the library of greater use to the members.

Your Council have considered in what way it was possible for them to reciprocate in this respect with these and other Societies, and they have adopted an organised plan, by which copies of our Transactions are to be regularly transmitted to them. The members will have become familiar with these Societies, as a list of them has been printed with Part IV. of our Transactions, for 1874.

The stock of Transactions of the Society, in hand and unsold, is very considerable, but, unfortunately, of some of the parts only a few copies remain. A limited number of complete copies of the Transactions have been bound in

six volumes, and can be purchased by the *members*, and the Council have noticed that an active demand for the past Transactions has taken place, and that once more an item of income from this source appears in the Treasurer's accounts of the past year.

The Library has been thoroughly examined and re-catalogued during the session. The bound volumes of books are now placed in a new bookcase in the entrance hall of the Society's rooms, and are available for the use of the members. The unbound periodicals, works, and pamphlets are in the course of binding and cataloguing, and the Council expect that this very onerous, but necessary labour will be shortly completed, and a new and useful catalogue of the Library as it now exists will be printed for the members.

The Financial Statement of the Treasurer, which is presented with this Report, shows that the receipts during the past year have been £303 12s. 1d., and the expenditure £153 9s. 5d., leaving a balance of £150 2s. 8d.

MANCHESTER GEOLOGICAL SOCIETY.

BALANCE SHEET, 1874.

Abstract of Receipts.	£	s.	d.
To Balance brought down	157	19	8
,, Subscriptions, 1873-4	72	0	0
,, Arrears of former years	31	0	0
,, Interest from Bank	4	11	0
,, Dividend, Birkenhead Stock	19	15	5
,, Proceeds of Furniture	8	2	0
,, Sale of Proceedings	10	4	0
	£303	12	1
To Balance brought down 25th October, 1874	150	2	8

HENRY M. ORMEROD, Treasurer.

Abstract of Payments.	£	s.	d.
By Library	4	5	6
,, Reporters	6	6	0
,, Transactions, Reports of Meetings, &c.	48	5	4
,, Postages, Stationery, &c.	15	15	7
,, Collector's Commission	5	3	0
,, Insurance	0	3	0
,, Furniture	20	9	0
,, Rent	7	10	0
,, Owens College, Share of Cleaning Collection, &c.	45	12	0
	£153	9	5
Balance	150	2	8
	£303	12	1

The Stock belonging to the Society consists of £500 Birkenhead Railway Stock, standing in the names of Henry Mere Ormerod and Andrew Knowles.

NEW ORDINARY MEMBERS, 1874.

W. A. Byrom, King Street, Wigan.

J. H. Johnson, Strangeways, Wigan.

NEW HONORARY MEMBERS.

Owen, Richard, M.D., D.C.L., LL.D., F.R.S., &c., Sheen Lodge, Richmond Park, S.W.

Harkness, Prof. Robert, F.R.S., F.G.S., Queen's College, Cork.

Hawkshaw, Sir John, Knt., F.R.S., F.G.S., &c., 33, Great George Street, Westminster, S.W.

Ormerod, Geo. Wareing, M.A., F.G.S., Brookbank, Teignmouth.

Ramsay, Prof. Andrew C., LL.D., F.R.S., &c., Director-General of the Geo. Survey of the United Kingdom.

Hull, Prof. Edward, M.A., F.R.S., &c., Director of the Geo. Survey of Ireland, 14, Hulme Street, Dublin.

Geikie, Archibald, L.L.D., F.R.S., F.G.S., Director of the Geo. Survey of Scotland, Ramsay Lodge, Edinburgh.

Agassiz, Prof. Alexandre, Cambridge, Boston, Mass., U.S.

Woodhouse, John Thomas, F.G.S., M.I.C.E., Overseal, near Ashby-de-la-Zouch.

Forster, Thomas Emerson, M.I.C.E., Blackworth, Newcastle-on-Tyne.

Morton, George Highfield, F.G.S., 21, West Derby Street, Liverpool.

Hawkins, B. Waterhouse, F.L.S., F.G.S., Century Club, East 15th Street, New York City.

MEMBERS DECEASED.

Louis Agassiz, M.D., LL.D.	Hon. Member.	
William Brooke, F.G.S.	Elected	1864
D. S. Clayton	„	1844
Sir William Fairbairn, Bart., D.C.L., F.R.S.	„	1838
Peter Higson, sen., F.G.S.	„	1838
Mark Philips	„	1838
Professor John Phillips, LL.D., F.R.S.	Hon. Member.	

LIST OF PAPERS AND SUBJECTS BROUGHT BEFORE THE ORDINARY MEETINGS OF THE SESSION.

1873.

Dec. 23. The President's Remarks.

„ Dickinson, Joseph, F.G.S., "On the Saliferous Strata."

1874.

Jan. 27. Aitken, John, F.G.S., "Notes on the Discovery of a new Fossil Fish of the genus *Acrolepis* (Ag.) in the Millstone Grit, near Hebden Bridge, Yorkshire."

„ Dawkins, W. Boyd, F.R.S., &c., "Communications upon the Registering of Glacial Boulders."

Feb. 24. Plant, John, F.G.S., "On Peat Fuels and their Economic Value."

„ Plant, John, F.G.S., "Mammoth Bones discovered at Lothersdale."

Mar. 31. Traice, W. H. J., "On Coal-cutting Machinery."

„ Spencer, James, "Additional Notes on the Millstone Grit of the Parish of Halifax."

„ Binney, E. W., F.R.S., F.G.S., "Letter on Permian and Trias Strata."

April 28. Plant, John, F.G.S., "On Pleistocene Mammalia found near Castleton, Derbyshire."

June Visit to Owens College to inspect the arrangement of the Collection of Fossils and Minerals which this Society had recently presented to the College.

,, 30. Circular read "On the Sub-Wealden Exploration Extension."

,, Aitken, John, F.G.S., "On the Occurrence of High Level Drift in the neighbourhood of Bacup."

,, Plant, John, F.G.S., "On the Occurrence of Quartzite Boulders and Pebbles embedded in true Coal."

,, Aitken, John, F.G.S., "Remarks on the Bone Cave of Windy Knoll, near Castleton," recently described by Mr. Plant.

The President moved, "That the report which had been read be accepted and printed as usual." He was sure there would only be one opinion, that it was an exceedingly gratifying and satisfactory report in every way, but especially as regarded the state of their finances. When societies like that could be worked so economically, it must greatly tend to their ultimate success, and although the meetings of that Society might not always have been attended so well as they could wish, still they could not but regard the Society as being in a very healthy and satisfactory position.

Mr. J. Dickinson seconded the motion, which was passed unanimously.

The President said that, by the new rules, it would be seen that the ex-Presidents would become, *ex post officio*, Vice-Presidents of the Society.

The following gentlemen were then unanimously elected officers and members of the Council for the ensuing year:—

President:

PROFESSOR W. BOYD DAWKINS, M.A., F.R.S., F.G.S.

Vice-Presidents:

JOHN AITKEN, F.G.S., *Ex-President.*
JOSEPH DICKINSON, F.G.S., *Ex-President.*
JOHN KNOWLES, M.I.C.E., *Ex-President.*
THOMAS KNOWLES, M.P., *Ex-President.*

Treasurer:

HENRY MERE ORMEROD.

Hon. Secretaries:

JOHN E. FORBES, F.G.S.
JOHN PLANT, F.G.S.

Of the Council:

E. W. BINNEY, F.R.S., F.G.S., *Ex-President.*
WILLIAM BRYHAM.
JOHN CROSS, Wigan.
SAMUEL CROWTHER.
R. D. DARBISHIRE, B.A., F.G.S.
G. C. GREENWELL, F.G.S., *Ex-President.*
W. H. JOHNSON.
KAYE KNOWLES.
CLEGG LIVESEY.
JOSEPH S. MARTIN.
CLIFFORD SMITH.
JOHN WILD.

Auditors:

JOHN HEELIS.
THOMAS LIVESEY.

Mr. PLANT then read the revised Rules of the Society, which were approved, and ordered to be printed.

Mr. J. Dickinson moved, "That a vote of thanks be given to the retiring President, Mr. Thomas Knowles, M.P."

This was seconded by Mr. Tonge, and agreed to unanimously.

Mr. Knowles, in responding, said he was exceedingly grateful for this mark of their confidence, which, he thought, he scarcely deserved. His attendance at their meetings had not been so regular as he could have desired; but this, he could assure them, arose from no fault of his own, but from causes over which he had no control. He had intended to read before the Society a Paper embodying his experience in mining matters, but the pressure on his time had prevented this; as soon, however, as he could find opportunity to complete this Paper he should be most happy to read it before the members.

The names of Mr. G. C. Greenwell, jun., Poynton; Mr. T. T. Wilkinson, F.R.A.S., Burnley; and Mr. W. H. Hewlett, were proposed and admitted as ordinary members of the Society.

LIST OF MEMBERS,

NOVEMBER, 1874.

The Names of Honorary Members are printed in *Italics.*

* Members who have compounded for the Annual Subscription.

Year of Election.	
1874	*Agassiz, Alexandre,* Cambridge, Massachussetts, U. S.
1863	Aitken, John, F.G.S., Bacup. *Ex-President.*
1862	Alcock, Thomas, M.D., Oak Field, Ashton-on-Mersey.
1865	Ashworth, Edward, Stag Hills, Waterfoot, near Manchester.
1864	Ashworth, John, Rose Hill, near Bolton.
1866	Bamford, J. B., Mining Engineer, Rochdale.
1859	Barr, William Roby, F.G.S., Park Mills, Stockport.
1859	Bazley, Sir Thomas, Bart., M.P., Cyford Park, Stow-on-the-Wolds.
1861	Beswicke, William, South Parade, Rochdale.
1838	Binney, E. W., F.R.S., F.G.S., 55, Peter Street, Manchester. *Ex-President.*
1867	Bolton, H. H., Newchurch, near Manchester.
1866	Brierley, Joseph, Civil Engineer, Blackburn.
1859	*Brongniart, Adolphe,* Jardin des Plantes, Paris.
1861	Brooks, Thomas, Sunnyside, Rawtenstall.
1859	Bryham, William, Rose Bridge Colliery, Wigan.
1861	*Buccleuch, His Grace the Duke of, Whitehall Gardens, London, S.W.
1874	Byrom, W. A., King Street, Wigan.
1860	Crowther, Samuel, Bradford Offices, Bolton.

Year of Election.	
1860	Charlton, F. P., junr., Highcroft House, Farnworth.
1861	Chattwood, Joseph, Park Bank, Higher Broughton.
1859	*Coulthart, J. Ross, F.R.S.L., Croft House, Ashton-under-Lyne.
1862	Cross, John, 78, Cross Street, Manchester.
1862	Cross, John, Gidlow House, Wigan.
1868	Craig, William Young, Alsagar, Stoke-on-Trent.
1869	Dawkins, Professor W. Boyd, M.A., F.R.S., The Owens College, Manchester.
1861	Derby, The Right Hon. the Earl of, Knowsley.
1860	Darbishire, R. D., B.A., F.G.S., 26, George Street, Manchester.
1856	Dickinson, Joseph, F.G.S., H.M. Inspector of Mines, South Bank, Pendleton. *Ex-President.*
1859	Diggle, James, Westleigh Colliery, Leigh.
1866	Eccles, James, F.G.S., 15, Durham Villas, Phillimore Gardens, Kensington, London, W.
1838	*Egerton, Sir Philip de Malpas Grey, Bart., M.P., F.R.S., Oulton Park, Tarporley. *Ex-President.*
1852	Egerton, The Hon. Algernon, M.P., Worsley Hall.
1838	*Embleton, T. W.*, The Cedars, Methley, Leeds.
1838	*Enniskillen, Earl of*, F.R.S., Florence Court, Fermanagh.
1860	Eskrigge, R. A., F.G.S., 17, Exchange Buildings North, Liverpool.
1865	Evans, Walter, Longsight, Oldham.
1863	Farrer, James, 12, Market Street, Bury.
1859	Forbes, John Edward, F.G.S., 5, York Street, Manchester.
1868	Fletcher, Thomas, Haulgh, Bolton.
1873	Fletcher, Herbert, The Hollins, Bolton.
1874	*Forster, T. W.*, M.I.C.E., Blackworth, Newcastle-on-Tyne.

Year of Election.	
1873	Garforth, W. E., Lord's Field Colliery, Ashton-under-Lyne.
1874	*Geikie, Archibald*, L.L.D., F.R.S., Ramsay Lodge, Edinburgh.
1859	Gerard, Sir R. T., Bart., Garswood, near Warrington.
1857	Gilroy, George, Ince Hall Colliery, Wigan.
1838	Greg, Robert Hyde, F.G.S., Chancery Place, Manchester.
1852	Greg, Robert Philips, F.G.S., Chancery Place, Manchester.
1863	Greenwell, G. C., F.G.S., Poynton, near Stockport. *Ex-President.*
1874	Greenwell, G. C., junr., Poynton, near Stockport.
1865	Grimshaw, Joseph, Kersley Mount, Stoneclough, near Manchester.
1838	Hadfield, George, 24, Fountain Street, Manchester.
1866	Hall, John, junr., Balderstone, Walmersley.
1864	Hall, Robert, Hope Foundry, Bury.
1861	Harbottle, W. H., Orrell Colliery, near Wigan.
1864	Hardwick, C., 74, Halston Street, Hulme.
1874	*Hawkins, B. W.*, F.L.S., Century Club, East 15th Street, New York.
1874	*Hawkshaw, Sir John*, Knight, F.R.S., 33, Great George Street, Westminster, S.W.
1861	Hawksworth, E., Coal and Iron Co., Crewe.
1860	Heelis, John, 37, Cross Street, Manchester.
1874	Hewlett, W. H., Coal and Iron Co., Wigan.
1838	*Heywood, James, F.R.S., F.G.S., 26, Kensington Palace Gardens, London, W. *Ex-President.*
1861	Heywood, Oliver, Acresfield, Pendleton.
1874	*Hull, Professor Edward*, M.A., F.R.S., 14, Hulme Street, Dublin.
1874	Johnson, J. H., Strangeways, Wigan.
1859	Johnson, Richard, 27, Dale Street, Manchester.
1872	Johnson, W. H., B.Sc., Wilmslow.

Year of Election.	
1844	*Joule, J. P., LL.D., F.R.S., Old Trafford, Manchester.
1856	Knowles, Andrew, High Bank, Pendlebury. *Ex-President.*
1859	Knowles, John, Westwood, Pendlebury. *Ex-President.*
1864	Knowles, Kaye, Swinton House, Pendlebury.
1861	Knowles, Robert M., Bromley Cross, near Bolton.
1859	Knowles, Thomas, M.P., Ince Old Hall, Wigan. *Ex-President.*
1844	Lancaster, John, F.G.S., Bilton Grange, Rugby.
1838	Langton, William, Mosley Street, Manchester.
1860	*Litler, H. William, Wallerscote, Leamington.
1861	Livesey, Clegg, Bredbury Colliery, near Stockport.
1838	Livesey, Thomas, Prestwich Park, near Manchester.
1838	*Lyell, Sir Charles,* Bart., D.C.L., F.R.S., &c., 73, Harley Street, London, W.
1862	Lynde, J. G., F.G.S., Town Hall, Manchester.
1873	Martin, Joseph S., Inspector of Mines, Park Villas, Prestwich.
1838	*Morton, Charles,* The Grange, Southport.
1874	*Morton, G. H.,* F.G.S., 21, West Derby Street, Liverpool.
1864	Nuttall, Thomas, Colliery Surveyor, Bury.
1874	*Ormerod, G. W.,* M.A., F.G.S., Brookbank, Teignmouth.
1838	Ormerod, H. M., Clarence Street, Manchester.
1874	*Owen, Professor Richard,* D.C.L., F.R.S., &c., British Museum, London, W.C.
1864	Park, James, Ironfounder, Bury.
1873	Pilkington, Edward, Clifton Collieries, near Manchester.
1873	Pilkington, Alfred, Clifton Collieries, near Manchester.
1858	Pickup, Peter, F.G.S., Townley Colliery, Burnley.

Year of Election.	
1851	Plant, John, F.G.S., Royal Museum, Peel Park, Salford.
1867	Radcliffe, James, Lord's Field Colliery, Ashton-under-Lyne.
1866	Radcliffe, Richard, Preston New Road, Blackburn.
1874	*Ramsay, Professor A. C.*, LL.D., F.R.S., &c., 29, Upper Phillimore Place, Kensington, W.
1860	Ridyard, John, Walkden, Worsley.
1861	Roscoe, James, Peel Hall, near Bolton.
1873	Seddon, T. F., Great Harwood Collieries, Accrington.
1866	Selby, Atherton, M.E., Leigh.
1858	Shuttleworth, Sir James P. Kay, F.G.S., Gawthorpe Hall, Burnley. *Ex-President.*
1864	Smethurst, William, Anderton Hall Colliery, near Chorley.
1838	Smith, G. Fereday, M.A., F.G.S., Grovehurst, Tunbridge Wells.
1873	Smith, Clifford, Parkfield, Swinton, near Manchester.
1866	Sopwith, Arthur, F.G.S., 103, Victoria Street, London, S.W.
1844	*Sopwith, Thomas*, M.A., F.R.S., F.G.S., 103, Victoria Street, London, S.W.
1861	Spence, Peter, F.C.S., Erlington House, Seymour Grove, Old Trafford.
1859	Statter, Thomas, Bury.
1859	*Trafford, Sir Humphrey De, Bart., Trafford Park.
1873	Tonge, James, Hulton Collieries, near Bolton.
1861	Wadham, Edward, Millwood, Dalton-in-Furness.
1861	*Walsh, Eli, Over Darwen.
1863	Webster, R. C., Ruabon Colliery, Ruabon.
1865	Whipp, Thomas, Sandy Lane, Bowdon.
1867	Wild, George, Bardsley Colliery, Ashton-under-Lyne.
1859	Wild, John, Glodwick, Oldham.

Year of Election.	
1860	Wild, Samuel, Dean House, Buersill, Rochdale.
1874	Wilkinson, T. T., F.R.A.S., Burnley.
1838	*Wilson, Thomas*, Hillary Place, Leeds.
1859	Woods, Henry, The Larches, Wigan.
1874	*Woodhouse, J. T.*, F.G.S., M.I.C.E., Overseal, near Ashby-de-la-Zouch.

PAST PRESIDENTS OF THE SOCIETY.

1838-9	Ellesmere, The Right Hon. the Earl of,
1839-40	Egerton, The Rt. Honorable Lord Francis, M.P.
1840-1-2	Heywood, James, F.R.S., F.G.S.
1842-3-4	Egerton, Sir Philip de Malpas Grey, Bart., M.P.
1844-5	Black James, M.D., F.G.S.
1845-6	Mosley, Sir Oswald, Bart.
1846-7-8-9	Thicknesse Ralph, M.P., Wigan.
1849-50	Heywood James, M.P., F.R.S.
1850-1-2-3	Black James, M.D., F.G.S.
1853-4-5	
1855-6-7	Egerton, Sir Philip de Malpas Grey, Bart., M.P.
1857-8-9	Binney, E. W., F.R.S., F.G.S.
1859-60-1	Kay-Shuttleworth, Sir J. P., Bart., F.G.S.
1861-2-3	Dickinson Joseph, F.G.S,
1863-4-5	Knowles Andrew.
1865-6-7	Binney, E.W., F.R.S., F.G.S.
1867-8	Greenwell, G. C., F.G.S.
1868-9-70	Aitken John, F.G.S.
1870-1-2-3	Knowles John, M.I.C.E.
1873-4	Knowles Thomas, M.P.

DONATIONS TO THE LIBRARY.—1873-4.

Geological Societies.

Edinburgh, "Transactions." Parts 1, 2, 3. Vol. II.
Glasgow, "Transactions." Part 3. Vol. IV.
London, "Quarterly Journal." Nos. 116, 117, 118, 119, 120. 1873-4.
,, "Abstracts of Sessions 1873-4."
,, Geologists' Association. "Proceedings of the Session," Vol III., 1874.

Literary and Philosophical Societies.

Leeds, "Annual Reports," 1872-3-4.
Leicester, "Annual Reports," and "Presidents' Addresses," 1867-74.
Manchester, "Proceedings." Vols. VIII., IX., X., XI., XII., XIII.
Bristol, Naturalists' Society. "Proceedings," 1872-4.
Warwick, Naturalists' Society. "Reports," 1872-3-4.
London, Royal Society. "Proceedings," 1852-3-4.
Birmingham, "Catalogue of Free Library of Reference," 1869.
,, "Twelfth Annual Report," 1873.

The United States Geological Survey.

From Dr. F. V. Hayden, U.S,, Geologist, Washington :—

"Contributions to the Extinct Vertebrate Fauna of the Western Territories," 4to.

Vol. I., "Fossil Vertebrates," by Prof. Joseph Leidy.

Vol. V., Part 1, "Acrididæ of North America," by Cyrus Thomas, Ph.D.

"Profiles, Sections, and Illustrations to the final Report of the Chief Geologist of the Survey of the Territories," 4to, 1872.

"Sixth Annual Report of the U. S. Geological Survey of Montano, Idaho, Wyoming, and Utah in 1872," 8vo, 1873.

"Synopsis of New Vertebrata from the Tertiary of Colorado," pp. 20.

"Lists of Elevations, West of the Mississippi," pp. 48.

"Meteorological Observations—during 1872 in Utah, Idaho, and Montana," pp. 120.

"First, Second, and Third, 1867-8-9, and Sixth Annual Reports of the United States Geographical Survey of the Territories for the year 1872," 8vo, 1873.

"Synopsis of the Flora of Colorado," by T. C. Porter and J. M. Coulter, pp. 180.

From E. T. Cox, State Geologist, Indianopolis, Indiana:—

"Third and Fourth Annual Reports of the Geological Survey of Indiana in 1871-2," 8vo.

"Case of Maps to the above."

From Verplanck Colvin:—

"Report on the Topographical Survey of the Adirondack Wilderness of New York," 8vo, 1873.

From T. M. Drown:—

"Transactions of the American Institute of Mining Engineers," Vol. 1., 1872-3, imp. 8vo. (*From the Council.*)

From G. C. Broadhead, State Geologist:—

"Geological Survey of Missouri. Preliminary Report of the Iron Ores and Coal Fields, from the fieldwork of 1872," imp. 8vo, 1873, with Atlas of 14 large Maps and Sections.

From G. C. Broadhead, F. B. Meek, and B. F. Shumard:—

"Reports on the Geological Survey of the State of Missouri, 1855-71," royal 8vo., 1873.

From Department of the Interior:—

"Bulletin of the U. S. Geological and Geographical Survey of the Territories. No. 1. Northern Colorado," pp. 28, 1874.

From the Board of Regents, Washington:—

"Annual Report of the Smithsonian Institution for the Year 1871," 1872, 8vo.

"Archives of Science of the Orleans County Society, Vermont, U.S." Nos. 4, 5, 8vo., 1871-2.

From A. R. C. Selwyn, Geological Survey of Canada:—

"Report of Progress for 1872-3," imp. 8vo.

"Report on the Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada," by J. W. Dawson, LL.D., imp. 8vo.

"List of Publications of the Geological Survey of Canada."

"Palæozoic Fossils," by E. Billings, F.G.S. Vol. II., Part 1, 1874, royal 8vo., pp. 144, with 9 Plates.

From South Wales Institute of Engineers :—

"Proceedings." No. 5., Vol. VIII., Dec., 1873; No. 6, 1874.

From the Editor :—

"Sitzungs-Berichte, Isis." April to Dec., 1873; Jan. to March, 1874. Dresden.

From Professor Owen :—

"Description of the Skull of a fossil Dentigerous Bird," pp. 12, 8vo.

From Professor Edward Hull, Dublin :—

"Geology of Building Stones," 8vo.

PURCHASED FOR THE LIBRARY.

"Geological Magazine." Vols. I.-X., 1864-73.

"Manual of Coal Measures Palæontology," by T. P. Barkas, F.G.S., with folio Atlas of plates, royal 8vo., 1873.

"The Great Ice Age, and its Relation to the Antiquity of Man," by James Geikie, 8vo., 1874.

"Palæontographical Society," publications for 1873-4.

SOCIETIES WITH WHOM THE SOCIETY EXCHANGES ITS TRANSACTIONS AND INSTITUTIONS AND JOURNALS TO WHOM A COPY IS SENT FREE.

I.—ENGLAND.

London..... British Museum.
Geological Survey.
Geological Society.

	Geologists' Association.
	Royal Institution.
	Royal Society.
Manchester	The Owens College.
	Literary and Philosophical Society.
	Free Library, Camp Field.
	Salford Royal Museum.
Liverpool	Geological Society.
	Free Library.
Leeds	Geological and Polytechnic Society.
	Free Library.
	Literary and Philosophical Society.
Leicester	Literary and Philosophical Society.
Birmingham	Free Library.
Cambridge	Geological Museum, University.
Oxford	Geological Museum, University.
Exeter	Free Museum and Library.
Cornwall	Royal Geological Society.
	Royal Institute.
Bristol	Naturalists' Society.
Warwick	Natural History Society.
Swansea	South Wales Institute of Engineers.
Barnsley	Midland Institute of Mining Engineers.
Dudley	Geological and Scientific Institute.
Newcastle-on-Tyne ..	Institute of Mining Engineers.
Sheffield	Free Library and Museum.

II.—Scotland.

Edinburgh	Geological Society.
	Royal Society.
	Royal Physical Society.
Glasgow	Geological Society.
	Natural History Society.
Dundee	Free Library.

III.—Ireland.

Dublin	Royal Dublin Society.
	Royal Geological Society.
Belfast	Natural History Society.

IV.—Foreign Societies.

Paris	Societie Geologique.
Geneva	Societie Palæontographie Suisse.
Berlin	Geological Society of Germany.
Turin	Academie Royale.
St. Petersburgh	Academy Imperial.
Christiania	Royal University of Norway.
Dresden	Natural History Society "Isis"
Calcutta	Geological Survey of India (Dr. Oldham).

V.—United States and Canada.

Washington, U.S.	Smithsonian Institution.
Columbus, U.S.	Ohio, Geographical Survey of (Dr. J. S. Newberry, F.G.S.)
Washington, U.S.	Dr. F. V. Hayden, U.S., Geologist.
Philadelphia, U.S.	H. Darwin Rogers, State Geologist.
New York, U.S.	*Silliman's Journal.*
Montreal	Geological Survey of Canada (A. R. C. Selwyn, F.G.S., Director).
	McGill College (Principal J. W. Dawson)
Boston, U.S.	Free Library.
New Haven	Professor O. C. Marsh, F.G.S.
Indiana	E. C. Cox.
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VI.—Australia.

Melbourne ..... Free Library.
Sydney ..... Free Library.
Newcastle ..... J. Mackenzie, F.G.S.

VII.—Scientific Journals, &c.

Quarterly Journal of Science, Geological Magazine, Nature, Science Gossip, Mining Journal, Colliery Guardian.

Record of Geological Literature.

IT has been decided to publish, as a yearly volume, a Record of Works on Geology, Mineralogy, and Palæontology, British and Foreign.

The first volume will be printed by the middle of 1875, and will contain short abstracts or notices of Papers, Books, Maps, etc., published during the year 1874. It is estimated that this volume will contain from 200 to 300 pages, and that its price will be 10/6.

The gentlemen named below have volunteered to assist in the work, which has already been begun. Those marked * have taken charge of various sections (as Sub-Editors), and the last has undertaken the post of General Editor.

REV. T. G. BONNEY, F.G.S.
*W. CARRUTHERS, F.R.S., F.G.S. (British Museum).
C. E. DE RANCE, F.G.S. (Geological Survey).
*R. ETHERIDGE, JUNIOR, F.G.S. (Geological Survey of Scotland).
D. FORBES, F.R.S., F.G.S.
DR. C. LE N. FOSTER, F.G.S. (Inspector of Mines).
PROF. GEIKIE, F.R.S., F.G.S. (Director of the Geological Survey of Scotland).
*PROF. A. H. GREEN, M.A., F.G.S.
T. M. HALL, F.G.S.
E. T. HARDMAN (Geological Survey of Ireland).
PROF. T. R. JONES, F.R.S., F.G.S.
A. J. JUKES-BROWNE, B.A., F.G.S. (Geological Survey).
*G. A. LEBOUR, F.G.S.
*L. C. MIALL (Leeds Museum).
HUGH MILLER F.G.S. (Geological Survey).
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E. B. TAWNEY, F.G.S. (Bristol Museum).
*W. TOPLEY, F.G.S. (Geological Survey).
HENRY WOODWARD, F.R.S., F.G.S. (British Museum).
H. B. WOODWARD. F.G.S. (Geological Survey).
W. WHITAKER, B.A., F.G.S. (Geological Survey).

The work will be greatly helped if Provincial Societies and Field Clubs will forward copies of their publications to the Editor.

It is hoped, from the low price, that the number of Subscribers (amounting to 200 before the issue of this Circular) will be enough to cover the expenses of printing; but should this not be the case, the following gentlemen have kindly consented to act as Guarantors:—

Dr. Bigsby, F.R.S., F.G.S.
E. W. Binney, Esq., F.R.S., F.G.S.
Rev. T. G. Bonney, F.G.S.
Dr. Bowerbank, F.R.S., F.G.S.
J. Brigg, Esq., F.G.S.
A Friend.
H. Cossham, Esq., F.G.S.
F. Crisp, Esq., F.Z.S.
C. Darwin, Esq., F.R.S., F.G.S.
T. Davidson, Esq., F.R.S., F.G.S.
J. Eccles, Esq., F.G.S.
Sir P. de M. G. Egerton, Bart., F.R.S., F.G.S.
The Earl of Enniskillen, F.R.S., F.G.S.
J. Evans, Esq., F.R.S. (*Pres. G. S.*)
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H. Willett, Esq., F.G.S.
S. V. Wood, Esq., F.G.S.

Names of intending Subscribers, and of Societies and Institutions that will purchase the Record for 1874, will be gladly received by the Editor.

W. WHITAKER,
Geological Survey Office,
Jermyn Street,
London, S.W.

November, 1874.

Palæontographical Society.

Report of the Council to a General Meeting, held at the Apartments of the Geological Society, Somerset House, London, on the 4th April, 1873.

PROFESSOR OWEN, F.R.S., IN THE CHAIR.

THE COUNCIL in presenting their Twenty-sixth Annual Report feel much pleasure in congratulating the Members on the wellbeing and continued success of the Society.

Financially, the twelve months now passed have been fruitful both in the acquisition of New Members and in the payment of back Subscriptions; matters of no slight importance in connection with the prosperity of the Treasurer's resources. The receipts have been far above the average. Not only was the amount collected (£948) considerable, it was in excess of any sum hitherto recorded in the Yearly Statements of the Council. All liabilities have been paid. No bills belonging to the last Volume remain unsettled. The Artists' charges also, in connection with the forthcoming Volume, have been defrayed in every case where proofs of the plates have been presented and approved.

With regard to the Publications of the Society, much progress has been made. The past year witnessed the issue of two Volumes, those pertaining to the years 1871 and 1872. The old arrears, therefore, so long a source of anxiety to

the Council, and so often an impediment in the acquisition of New Subscribers, have been overcome.

These Volumes (for the years 1871 and 1872) contain much valuable matter bearing upon several diverse branches of Palæontological Science. In the work for 1871 appears the first portion of a Supplement to the Crag Mollusca (Univalves), by Mr. Searles Wood, a veteran contributor, whose researches on the same class of past organisms formed the introduction to the series of the Society's Publications more than a quarter of a century since. The Supplementary Memoir on the Crag Univalves is illustrated by an original and very elaborate Map with Sections of the Crag District showing the geology of the Newer Tertiaries, in that part of England. The Map itself was drawn and presented by Mr. Searles Wood, Jun., and is elucidated by a paper on the same geological region, contributed by that gentleman and Mr. F. W. Harmer. The cost of colouring the Map, although partly paid for by the Society, is in the main the gift of those Authors.

In the Volume for 1872 appeared the first part of a Monograph on the Trigoniæ, by Dr. Lycett, previously a contributor in conjunction with Prof. Morris, and one of the authors of the Memoir on the Great Oolite Mollusca. The illustrations to this work, printed in Paris, are fine examples of Lithography.

The other Monographs comprised in the two Volumes are continuations of previous subjects by Mr. Binney, Prof. Duncan, Dr. Wright, Mr. Woodward, Prof. Owen, and Messrs. Boyd Dawkins and Sanford, and refer to the Carboniferous Flora, the Oolitic Corals, the Cretaceous Echinodermata, the Fossil Merostomata, the Iguanodon, and the Pleistocene Mammalia.

In reference to the Volume for the present year (that for 1873) much progress has been made. The whole of the Plates, with a very few exceptions, are finished; nearly

half the MS. is with the Printer and many sheets in type. More Manuscript is also available and is in the Secretary's hands. In this Volume Mr. Davidson will commence a Supplementary Work on the Brachiopoda, Mr. Searles Wood will continue his Supplement to the Crag Mollusca, by the addition of the Bivalves, Dr. Wright will proceed with the Cretaceous Echinodermata, and Prof. Owen will publish new parts in connection with the Wealden Reptilia.

Preparation is being made for the Publication of the Volume for the year 1874, of which many Plates are ready and paid for. The Contents will comprise, amongst others, the Post-Tertiary Entomostraca, by the Rev. H. W. Crosskey and Messrs. G. S. Brady and D. Robertson, the Carboniferous Entomostraca, by Prof. Rupert Jones, and a continuation of the Trigoniæ, by Dr. Lycett.

At the present moment there are in existence 74 plates, of which the whole, as far as the Artists are concerned, will be no further cost to the Society, and of which several, long since printed off, are in stock and paid for. The plates refer to Tertiary Plants, Cretaceous Echinodermata, the Crinoidea, Post-Tertiary and Carboniferous Entomostraca, Tertiary and Secondary Mollusca, and Secondary Reptilia.

In conclusion, the Council solicit help from all lovers of Geological Science, in their efforts to depict and describe the British Fossils. Already the sum of £18,000 has been expended in the elucidation of the organisms entombed in the Strata of Great Britain, and 26 Quarto Volumes have been published written by the best Palæontologists of the day.

Yet the 3933 species described in those 26 Volumes are but a fraction of the total waiting inspection. The completion of the great work can only be effected by the mutual co-operation of the Scientific Public, the outlay of large funds, and careful research on the part of many workers.

The PALÆONTOGRAPHICAL SOCIETY, *in Account with* SEARLES V. WOOD, ESQ., *from March 31st*, 1872, *to March 25th*, 1873.

	£	s.	d.
By Balance from last Account	102	5	11
Subscriptions from 5 Members for 1848	5	5	0
Ditto 5 „ 1849	5	5	0
„ 4 „ 1850	4	4	0
„ 7 „ 1851	7	7	0
„ 4 „ 1852	4	4	0
„ 5 „ 1853	5	5	0
„ 4 „ 1854	4	4	0
„ 6 „ 1855	6	6	0
„ 9 „ 1856	9	9	0
„ 6 „ 1857	6	6	0
„ 8 „ 1858	8	8	0
„ 6 „ 1859	6	6	0
„ 8 „ 1860	8	8	0
„ 10 „ 1861	10	10	0
„ 12 „ 1862	12	12	0
„ 12 „ 1863	12	12	0
„ 10 „ 1864	10	10	0
„ 11 „ 1865	11	11	0
„ 14 „ 1866	14	14	0
„ 12 „ 1867	12	12	0
„ 14 „ 1868	14	14	0
„ 21 „ 1869	22	1	0
„ 33 „ 1870	34	13	0
„ 144 „ 1871	151	4	0

	£	s.	d.
Paper	66	15	0
Letter Press Printing	245	4	0
Lithographic Printing	201	2	9
Drawing and Wood Engraving	105	16	10
Binding	128	13	7
Distribution of Books	36	4	6
Insurance, Advertisements, Postage, and Petty Expenses	19	19	1
Gratuity to Secretary	52	10	0
Balance in hand	194	13	2

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART VII. VOL. XIII. SESSION 1874-5.

At the ORDINARY MEETING of the members, held at the Literary and Philosophical Society's House, on Tuesday, 24th November, 1874.

Professor W. BOYD DAWKINS, M.A., F.R.S., President of the Society, in the Chair.

There was a good attendance of the members and visitors.

The following gentlemen were proposed as Ordinary Members of the Society:—The Rev. Addison Crofton, Wyngate House, Levenshulme; Captain Henry Allen Gun, R.E., F.G.S., Royal Engineers' Offices, Manchester.

INAUGURAL ADDRESS

BY THE PRESIDENT, PROFESSOR W. BOYD DAWKINS, M.A., F.R.S., F.G.S., &c.

It is generally considered the duty of the President, in taking the Chair, to deliver an Address, either on the progress which has been made by the science which he represents in the last session, or on some department of special research, in which he himself is more particularly interested. The inexorable demands on my time forbid, alas! the performance of either of these duties fully and thoroughly. I shall therefore merely give a short analysis of the most important additions to our knowledge since the

last session, which occur to me in those departments of the many-sided science of Geology that relate to mining, engineering, and terrestrial physics.

The Workable Depth of Coal.

Since the delivery of the last Address, two facts of considerable value in coal-mining have been ascertained. It will be in the memory of those who read the Report of the Coal Commission of 1871,* that the limit of the depth at which coal could be worked was fixed by the temperature of the blood, or 98°, at which, according to Dr. Burdon Sanderson, "labour is not practicable, except for very short intervals, in the moist air which is generally met with in mines."

"The evidence having shown that the question of maximum temperature under which work could be carried on in a coal mine hinges in a great measure on the hygrometric condition of the air, the Committee proceeded to inquire what was the state of the air in regard to moisture in coal mines? The observations which they collected on this point show that the air at the working faces of the coal was always humid, and often saturated with moisture. In general, however, the deepest collieries appear to be the driest, although there does not appear to be any ratio between depth and dryness. The depth at which the temperature of the earth would amount to blood heat, or 98°, is about 3000 feet. Under the long-wall system of working, a difference of about 7° appears to exist between the temperature of the air and that of the strata at the working faces; and this difference represents a further depth of 420 feet; so that the depth at which the temperature of the air would, under present conditions, become equal to

* Coal Com., 1871, p. viii.

the heat of blood, would be about 3420 feet. Beyond this point the considerations affecting increase of depth and temperature become so speculative, that the Committee felt it necessary to leave the question in uncertainty; but, looking to possible expedients which the future may elicit for reducing the temperature, they considered it might fairly be assumed that a depth of at least 4000 feet might be reached."

The deepest workings which afforded data in coming to this conclusion were:—

The Pendleton Pit	2214 ft. deep.
The Rosebridge Pit.....	2376 „
A Colliery near Charleroi, in Belgium.	2640 „
A Colliery at St. Gilly*	3000 to 3280 ft.

The last of these had been abandoned, though not on account of the heat at that depth.

Since these facts were brought before the Commissioners, another Belgian mine has been successfully carried to a greater depth than any of the above. I am informed by my friend Mr. Hunt, F.R.S., that the colliery at Echelles de Simont Lambert du Charbye des Vivières was 1040 metres, or 3511 feet, about three years ago. Thus the limit of 3420 feet has been already surpassed, without, so far as I know, any unusual difficulty having arisen from the temperature, of such a nature as to cause the adoption of extraordinary means of ventilation. It seems, therefore, very probable that the difficulties offered to the sinking of mines at a greater depth even than 4000 feet can be overcome by the genius of our engineers, and that by means of increased ventilation and the widening of the shafts the temperature may be reduced, so as to allow coal being worked considerably below the limit chosen by

* The evidence as to this mine is not at all complete.

the Commissioners in their estimate of the amount of coal available in this country. At all events, it is satisfactory to know that in Belgium coal is being worked now at a depth greater than any of our collieries by more than one thousand feet.

On this question, it is interesting to note in the last *Athenæum* that the Prussian engineers have bored, at Sperenberg, twenty-five miles south of Berlin, to a depth of more than 4040 feet in the saliferous rocks, which they struck at a depth of 283 feet. [*Athenæum*, Nov. 21, 1874, p. 283.]

A Cause of Explosions in Mines.

To Mr. W. Galloway, one of H.M. Inspectors of Mines, we are indebted for the demonstration of the mode in which some of the worst explosions in collieries have been produced. In an elaborate paper before the Royal Society, in May, 1874,† he has pointed out the intimate relation which exists in the cases, which have come under his observation, between the explosion of the gas and the firing of shots. In the majority of cases, the explosion is not due to the direct firing of the inflammable gas by the shot, but to the *concussion of the air, or the sound-wave, which causes the flame of the safety-lamp to pass through the gauze and ignite "the fire-damp,"* sometimes at a considerable distance from the point of firing. This position he has supported by a series of carefully-conducted experiments.* The disaster at the Oaks Colliery, in 1866, when 334 men lost their lives; that of Ferndale in 1867, where 178 men were killed; and that of Seaham, in 1871, with a loss of 26 men, are among the more prominent instances which he brings forward of

† Proceed. Royal Soc., vol. xxii., p. 441. 1874.

* Dr. Roscoe verified this conclusion by a beautiful experiment in his public lecture, at Owens College, on 14th December.

explosions traceable to the air-wave caused by the shot. If, then, this cause of explosion be fully recognised, the removal of all safety-lamps from the places in which they are surrounded by fire-damp, when shots are fired, will, beyond all doubt, considerably lessen the average number of explosions, and prevent the expenditure of human life. The delusion that a safety-lamp is safe under all conditions has led to the loss of many valuable lives, and the recognition of the fact that it is most dangerous when it is traversed by a wave of vibration in an atmosphere of fire-damp will certainly remove one element of peril in coal mining. This important truth is worthy of the careful attention of all men connected with the working of coal pits.

The Tunnel from England to France.

In the department of Applied Geology, Professor Prestwich's paper† on the construction of a tunnel between England and France, read before the Institute of Civil Engineers, deserves especial notice, not merely because it relates to an enterprise of international importance, but because it shows the intimate relation which exists between Geology and Engineering. After giving an account of the strata which compose the surface on either side of the Channel, and showing that the often serious, if not unsurmountable difficulties, to successful tunnelling, mainly on account of the vast quantities of water which they contain below the sea level, he proceeds to show that the palæozoic rocks underneath do not present the same difficulties, because they are protected from the influx of water by the mesozoic rocks which rest on their water-worn edges, and thus form a natural puddling or grouting. He supports this view by quoting the dry workings in the Belgian coal-fields, where

† Inst. Civil Engineers, Dec. 9, 1873.

the edges of the coal measures are covered by mesozoic strata of the same kind as those on the coasts of the Channel. The depth below the sea level, at which these palæozoic rocks may be expected to be found, is estimated at 750 feet at Boulogne, from 650 to 700 feet at St. Margaret's, and at Folkstone at not more than 300 or 400 feet.

If this great tunnel be ever taken in hand (and when such works as the tunnel through Mont Cenis have been completed we need not despair of its accomplishment), Professor Prestwich's paper will form a valuable basis, and we shall see in a concrete form the value of geological theory worked out into practice by the highest skill of the engineer. In cases such as this, it may be said that geological theory bears the same relation to engineering practice, as faith to works in the world of morals.

The Sub-Wealden Exploration.

The enterprise of reaching the palæozoic rocks through the overlying secondary strata at Netherfield, near Battle, which was begun in 1872 by the Sub-Wealden Exploration Committee, is still being carried on in spite of numerous obstacles, and without the least pecuniary gain being possible to the promoters, in the event of its being crowned with success. The total depth of the boring at the present time is 1030 feet, or within two or three hundred feet of the probable position of the palæozoic rocks, which it is designed to reach. The section is as follows :—

4. Purbeck marls and impure limestones, with 30 feet of gypsum in lower portions.....	180 „
3. Portland sandy and cherty beds.....	110 „
2. Kimmeridge clay.....	660 „
1. Oxford clay	80 feet.
	1030 feet.

The first 313 feet were bored with a steel drill nine inches in diameter, and the rest by the diamond boring process, with "a crown" or cylinder of soft iron charged with diamonds (carbonado), and with a diameter of 3½ inches. It will be observed that in the above section the calcareous or sandy beds of the Coral Rag or Coralline Oolite are unrepresented, and that consequently the Kimmeridge rests on the Oxford clay.

The Committee by whom this work is being carried on are fully aware of the uncertainty as to what member of the palæozoic rocks will be discovered at the bottom of the boring; but they are persuaded that the information which they will gain will be of great value as a guide to further researches, in which the true position of the buried coal-measures will ultimately be revealed, which connect the coal-fields of Somerset with those of Belgium and Northern France. The sinking, therefore, at Netherfield is of the highest interest, not merely on account of the additions to our knowledge of the distribution of the secondary rocks, but because it will probably lead ultimately to the discovery and working of the coal-measures in south-eastern England, and thus put off the evil day when our available stores of coal will be used up, and when our manufacturing enterprise will depart to other lands well stored with coal, leaving England to relapse into the agricultural condition from which she has emerged.

The importance of this being carried out has been so fully recognised by the Royal Society, the Geological Society, and the Institute of Civil Engineers, that a joint application to the Chancellor of the Exchequer has resulted in a Government grant of £1000, or one pound for each foot bored (which costs £3), from 1000 to 2000 feet, in aid of this costly undertaking. The result will have a most

important bearing on the projected tunnel between France and England.

The Source of Volcanic Heat.

In the department of physical Geology, the most important addition to our knowledge has been made by Mr. Robert Mallet, F.R.S., in a paper on "Volcanic Energy," read before the Royal Society in 1872,* and published in the last number of the Philosophical Transactions. In it he shows the various relations and points of connexion between volcanic phenomena, earthquakes, and the lines of mountain elevation, which imply that they are the results of the play of "one set of cosmical forces" which have been brought into operation by the gradual cooling of the earth from an incandescent sun-like state to its present condition. His argument is as follows:—As the cooling of the earth proceeded, the crust gradually thickened and contracted less and less as the temperature became lowered. The hotter nucleus, on the other hand, contracted more, being at a higher temperature than the crust, and having a higher co-efficient of contraction for equal loss of heat. By this process, which is still going on, the crust of the earth would shrink at one rate, and the vastly hotter central portion at another and greater rate, and thus cavities would be formed between the crust and the nucleus—cavities which would be inevitably filled by the *crushing down* of the solid crust on the more swiftly contracting nucleus, by the force of gravitation, which is sufficient to crush the hardest rocks. And as the solid crust follows the shrinking nucleus, "the *work* expended in mutual crushing and dislocation of its parts is *transformed* into *heat*," by which, at the points of crushing, the rocks are heated even to fusion. The access

* Phil. Trans., vol. 162, p. 143,; Proceed. Royal Soc. xx. 438.

of water to such points determines volcanic eruption. These points of crushing may occur at various depths in the solid crust.

He then proceeds to measure the amount of actual contraction by the annual amount of heat lost by radiation into space, which is sufficient to liquify 777 cubic miles of ice into water at 32°, and comes to the conclusion that less than one-fourth of total annual loss of heat would suffice to produce the contraction necessary for his hypothesis. The actual amount of annual contraction is estimated at a reduction of 3·5† inches on the earth's radius, an amount too small to be measured by any astronomical method, and yet more than enough to produce all the volcanic phenomena now to be observed on the surface of the earth.

These conclusions are tested by a series of carefully-conducted experiments on the amount of heat capable of being developed by crushing various kinds of rocks. They seem to me to offer a satisfactory explanation of earthquakes and volcanoes, hitherto accounted for by various unsatisfactory speculations. Their bearing on the general great physical history of the earth may best be explained in the words of their able author. ‡

"In the source that has been pointed out as that from which volcanic heat is itself derived, viz., the secular cooling of our globe, and the effects of that upon its solid shell, we are enabled to point to that which is the surest test of the truth of any theory—that it not only enables us to account for the phenomena, near or remote, but to predict

* I can account in no other way than this for the glazed surfaces in some cases of slickensides in loose gritstone rocks, such as those which Mr. Aitken has described in the Transactions of this Society.

† Proceed. Royal Soc. xxii., 328.

‡ Palmieri, "Vesuvius." Introd., p. 173.

them. We see here linked together, as parts of one grand play of forces, those of contraction by cooling, producing by *direct* mechanical action the elevation of mountain chains, and by their *indirect* action by transformation of mechanical work into heat, the production of volcanoes; and both by direct and indirect action of earthquakes, never previously shown to have thus the physical connection of one common cause, but merely supposed, more or less, to be connected by their distribution upon our earth's surface.

"We now discern thus the physical cause *why* volcanoes are distributed, viewed largely, linearly, and follow the lines of elevation; we see equally why their action is uncertain, non-periodic, fluctuating in intensity, with longer or shorter periods of repose, shifting in position, becoming extinct here, appearing in new activity or for the first time there. We have an adequate solution of the before inexplicable fact of their propinquity, and yet want of connection. We have an adequate cause for the fusion of rock at local points, without resorting to the baseless hypothesis of perennial lakes of lava, &c. For the first time, too, we discern a true physical cause for earthquake movement, where volcanic energy does not show itself. The crushing of the world's solid shell, whether thick or thin, goes on *per saltum* and at ever-shifting places, however steadily the tangential pressures producing it may act. Hence crushing *alone* may be shown to develope amply sufficient impulse to produce the most violent earthquakes, whether they be or be not, at a given place or time, connected with volcanic outburst or dossible injection, or with tangential pressures, enough still, in some cases, to produce partial permanent elevation.

"When subterraneous crushing takes place, and the circumstances of the site do not permit the access of water, there may be earthquake, but can be no volcano; where water is admitted, there may be both.

"And thus we discern why there are comparatively few submarine volcanoes, the floor of the ocean being, on the whole, water-tight—puddled, as an engineer would say, by the huge deposit of incoherent mud, &c., that covers most of it, and probably having a thicker crust beneath it than beneath the land. We see, moreover, that the geological doctrine of absolute uniformity cannot be true as to vulcanicity, any more than it can for any other energy in play in our world. Its development was greatest at its earliest stages, when the great masses of the mountain chains were elevated. It is even now—though as compared to man's experience, and even to all historic time, apparently uniform and always the same—a decaying energy.

"The regimen of our planet as part of the Kosmos, which seems to some absolute (and presented to Playfair no trace of a beginning nor indication of an end), is not absolute, and only seems to us to have been so because we see so little of it, and of its long perspective in time. This the now established doctrine of the conservation of energy renders certain.

"With this source for volcanic heat, too, in our possession, we can look from our own world to others, and predict, within certain limits, which must widen as our knowledge of the facts of their substance and surface become greater, what have been and what are the developments of volcanity which have taken place or are occurring in or upon them. Looking to our own satellite, we see for the first time a sufficient physical cause for the enormous display of volcanic energy there which the telescope divulges to us; one which is not to be explained alone by the commonly made statement of the small density of the moon, but by the fact that as the rate of her cooling from a given temperature, as compared with that of our earth (apart from questions of the chemical nature of the

two bodies, or of their specific heats, &c.), has been inversely as their respective masses, and directly as their surfaces," so the contraction has been greater and swifter, and the consequent development of heat by crushing also greater.

The Ancient Volcanoes of Scotland.

In the same department of Geology, Mr. Judd's* contribution to the history of the ancient volcanoes of Scotland deservedly stands pre-eminent. In it he shows that there were two great periods of volcanic activity—the one post-silurian, and continuing till the close of the Permian; the other post-cretaceous, and continuing till the close of the Meiocene age. In both these periods the phenomena were the same, a great outburst of light, siliceous, or acid rock (felstone, pitchstone, &c.), being followed by an eruption of heavy or basic material (basalt, trap, lava, &c.) from the same vents. And in both these periods, after the great vents had been blocked up, smaller secondary vents, or "puys," were developed in the neighbourhood, which mark a decadence of the volcanic energy. He estimates the base of the volcanic cone, which was in eruption in the Island of Mull in the Meiocene age, as being forty miles in circumference, and the minimum height at 10,000 feet, and proves that in those times a range of volcanic mountains on the grandest scale rose on the north-western side of Scotland. The volcanoes of the north of Ireland were in eruption at the same time, as may be seen by the Meiocene forest, which lies buried under the basaltic lava of Antrim.

Mr. Judd's essay is well worthy of the attention of all petrologists, since it shows how the more largely crystalline rocks of the acid and basic groups graduate into the more finely-grained and glassy forms, and that the

* Quart. Geol. Journ. xxx. 220.

plutonic rocks are merely those which have been cooled at the roots of volcanoes, while the volcanic are the same rock materials which have cooled at or near the surface. In other words, the terms "plutonic" and "volcanic" merely relate to position and rate of cooling.

The Rhine in the Meiocene Age.

We are indebted to Professor Ramsay, F.R.S., for a further contribution to the Meiocene Geography of Europe,* in which he shows that the Rhine did not then flow from the Alps into the North Sea, but in a contrary direction from the palæozoic rocks of Hunsrück and Taunus southwards, so as to debouch into the Mediterranean area.

Taking, indeed, a general view of the physical changes which intervened between the close of the Meiocene and the beginning of the Pleiocene period, it is important to notice that the last great elevation of the Alps and the Pyrenees was simultaneous with the depression of the north of Germany and of Britain, by which the course of the Rhine was reversed, and the crag-sea of the Pleiocene extended over Norfolk, Suffolk, and into Belgium, as well as with the shifting of the volcanic foci from the British Isles to other regions. That this period of movement in the crust of the earth should coincide with the shifting of the centres of volcanic disturbance, is consistent with the views which are held by Mr. Mallet.

Gradation of Permian into Carboniferous Strata.

Among the more important papers relating to the Carboniferous period, that of Dr. Dawson† on the upper coal formation of Eastern Nova Scotia and Prince Edward's

* Quart. Geol. Journ. xxx. 81.

† Quart. Geol. Journ. xxx. 209.

Island deserves especial notice. In it he shows that in those districts the upper Carboniferous rocks graduate into the Permian series in such a manner as to render an accurate division between them impossible. He accordingly groups them as Permo-Carboniferous. In holding this view, he strengthens the position advanced by Mr. Binney, that the Permian strata are to be looked upon as a mere upper division of the Carboniferous series, to which they are closely united, not only in the forms of marine life which they contain, the fishes and the mollusca, but in the land-flora, which is composed mainly of degraded and dwarfed representatives of the true Carboniferous type. It seems to me that the Carboniferous formation is related to the Permian in the same way as it is to the Devonian. The Carboniferous fauna and flora began to live in the last of these periods, and, after reaching their prime, ultimately became extinct in the Permian.

The Definition of the Glacial Period.

The last point which is left to me to notice is the result of the many essays which has been written during the last twelve months on Glacial phenomena. The researches of Campbell, Jamieson, Ward, Mackintosh, Geikie, and others, have proved that the ice sheets descended from centres of dispersal which are now the mountains and higher grounds of Europe. The speculation that a large portion of the northern hemisphere was covered by an ice cap which was developed in the north and extended uninterruptedly to our latitudes, seems to me to be unsupported by evidence; and the classification of the Glacial Deposits, proposed by Mr. James Geikie [Ice Age, 1873], into more than the old three divisions, however useful it may be in restricted areas in Scotland, does not apply to those of England. Taking a general view, three divisions of the

Glacial phenomena are only to be recognised over Europe in the present state of our knowledge—first, those of the age of severe cold, or of the ice-sheet, or the era of the lower boulder clay; secondly, those of the interglacial temperate age, marked in Lancashire by the shingle of the "Middle Drift," and in Switzerland by the interglacial forest of Dürntend; and lastly, those of the age of glaciers, when the cold was severe, but not so severe as in the first age. This last has left its mark in the upper boulder clay and the local moraines, and scratches running parallel into the courses of the present valleys in this district. The number three, in spite of its occurring so often in Geological classification as to cause us to be suspicious, is nevertheless true in this particular case. And it is very probable that the Arctic mammalia, the reindeer, and musk sheep, and the like, were living in southern France *during the time of* the minimum temperature marked by the ice-sheet in northern Britain, and that, as the cold increased, they retreated southwards before it in the preglacial age. If this view be held, it is by no means unlikely that man dwelt in Auvergne before the glacial period had set in in its full intensity in this country; in other words, that, like the other Arctic animals, he was driven to the south by the severe cold.

In the discussion of the glacial phenomena, it is important to bear in mind that "the glacial period" is a mere episode in the Pleistocene life-period, and that it is not a term of equal value with Eocene, Meiocene, Pleiocene, and the other divisions of the Tertiary series. It relates only to the climate of the Pleistocene, and ought not to be used in any other sense in geological classification. In the same manner the Meiocene and Permian "glacial periods" merely relate to certain parts of the Meiocene and Permian strata, where the cold, from high elevation or other causes,

was severe enough to produce ice action. They relate solely to local phenomena of temperature. If we use a low temperature as a means of classification, why should we not equally use a high one, and have not merely glacial, but tropical periods? No geologist would venture to substitute the latter term for a life-period such, say, as the Eocene.

My task is now ended. The past year has been fruitful not merely in the invention of new theories, but in the discovery of new facts, which come home to every practical geologist. In the coming session may we not expect similar fruits? And is it too much to hope that our Society will not be backward in adding to the general store of facts, from which are distilled from time to time those truths that are an heritage to men and a joy for ever?

Mr. John Knowles: I beg to propose the thanks of the meeting to the President, for the most interesting and scientific address with which he has favoured us. It contains allusions to several topics of great importance in the present day, but which it is not usual to discuss on this occasion; they are, however, well worthy of careful consideration by the proprietors of coal mines and Geologists.

Mr. John Aitken said he seconded the resolution with much pleasure, and he felt bound to congratulate the members of the Society upon having as their President a gentleman who has made himself a name—he might say even, is renowned—in Europe and America for his researches and discoveries in Quaternary Geology. He must also congratulate the meeting in having had the pleasure of listening to an address so important and instructive. It would be out of place, and he believed it was not customary in their Society, to discuss the points touched upon in an inaugural address, but he must claim their indulgence if he

transgressed a little to make a brief reference to one point raised by Professor Dawkins—namely, that which related to the inter-glacial periods, which have been recently brought into great prominence by Mr. James Geikie in his recent work, "The Great Ice Age." The author of that certainly interesting work, has made the discussion of this point one of the leading subjects in his book, and there can be few who study the subject but will admit that it is a point of some importance, and almost compels an earnest attention. He would have been glad if, in his address, Professor Dawkins had given them the benefit of his opinions, which, they would all admit, would be of considerable value in the present aspect of the question.

The vote of thanks was then unanimously carried.

The President said he had upon the table a new model, showing the geology of the Weald, made by Mr Topley, at the sides of which, it would be seen, the palæozoic rocks were put in about the place they are thought to be. He supposed in a short time they would find out whether it was really accurate; but the model afforded a very good idea of the opinion of the leading Geologists—Professor Prestwich and others—as to the precise position of these palæozoic beds. The specimens on the table illustrated different stages in the Weald boring by cores taken from depths of 300 to 700 or 800 feet; they showed the effect of the enormous pressure of the superincumbent rock in altering the texture of the Kimmeridge and Oxford clay. These hard, stone-like cores which he exhibited, were nothing but Kimmeridge, or Oxford clays, greatly pressed, which, if they were subjected to the action of the weather for a short time, would crumble to pieces. He had also specimens of gypsum, met with in the boring. A large deposit of gypsum was found not less than thirty feet thick, and it was of tolerable

commercial value—at all events, of sufficient value to have caused a Company to be formed for the purpose of working it. That was only one of the beds which they happened to work through. The President briefly explained the system of diamond boring pursued in the operations in the great Weald exploration.

Mr. Clifford Smith: How deep below the surface is the bed of gypsum you have described?

The President: I think about 200 feet, at all events not more than that—probably from 180 to 200. It is a very singular thing that the Prussians should have stolen such a march upon us as to have bored to a depth of 4040 feet. I do not know what their object is, but they have been boring through the saliferous marls. It is rather hard that the English—great miners, as we are considered—should be "cut out" by the Prussians in this way.

Mr. Aitken asked if any record had been obtained of the temperature at the depth mentioned in the Prussian borings?

The President: I am not aware that any observations of the temperature of the strata were observed; in fact, I have no knowledge beyond the record of the actual depth of the borings.

The meeting then adjourned.

At the Ordinary Meeting, held on Tuesday, December 23rd, 1874.

John Knowles, Esq., ex-President, in the Chair.

The name of Arthur W. Waters, Esq., F.G.S., Woodbrook, Alderley Edge, was submitted to the meeting, and he was elected, as an ordinary member of the Society.

Donations to the Library:—

It was announced that Professor Dawkins, President, had presented a copy of his recently published work, "Cave Hunting;" that Mr. J. Plant had presented a copy of Professor Aifsted's "Geology of Charnwood Forest," folio, illustrated with Photographs by Mr. Plant; that Mr. J. Dickinson had presented a copy of his engraved "General Sections of the Lancashire and Cheshire Coal Measures," issued in 1858.

It was reported to the meeting that the Council had selected a number of valuable and useful works on Coal Mining, Geology, and Coal-measures Palæontology, for purchase, to add to the Library.

FISH REMAINS FROM THE COAL MEASURES.

Mr. John Aitken, F.G.S., exhibited two specimens of fish and several teeth, principally from the Lancashire Coal Measures, and described the specimens as follows:—

Nos. 1 and 2 are two specimens of a new and undescribed Ganoid fish of the genus *Pygopterus*, which I recently discovered in a slab of shale from over the Arley mine of coal at Copy coal pit, in the Cliviger Valley, near Burnley. The slabs exhibit the fish laid on its side, with the exception of the head, which presents the upper surface to view. Both sides of the fish are exhibited, showing the form of the head, tail, and fins with marked distinctness. The head is long and comparatively narrow, and ornamented by the presence of well marked, long, waving ridges, which traverse it throughout its entire length. The scales are rhomboidal in shape, about one-eighth of an inch in length across their longest axis, and are highly sculptured, having about six

or eight distinct waving ridges and furrows crossing them almost parallel with their sides, and in a line with the body of the fish. The tail and fins are also well shown, the former being well defined and very large in proportion to the size of the fish, measuring across from point to point 2¼ inches; whilst the total length of the specimen only reaches 5½ inches, and the breadth of the body at its widest part one inch. The head is bent round so as to bring the snout to within about three-quarters of an inch from the lower lobe of the tail.

No. 2 is a tooth of *Rhizodus Hibberti* (Ag.), from the Blackband ironstone, Denhead, Fifeshire. The bed from whence this tooth was procured is situated low down in the carboniferous limestone series of Scotland. Teeth of this genus have not as yet been found in the true Coal Measures of England, and it is a moot point with ichthyologists whether their origin should be referred to fish or to some reptile of the *Labyrinthodont*, or other closely allied order. The specimen exhibited is in a good state of preservation, but small, being only two inches in length, whilst some teeth of this genus are known to reach fully six inches or more in length.

No. 4 is a rare palatal tooth named, *Psephodus magnus*, from the Arley mine of the Middle Coal Measures, Burnley. Its form is that of a truncated or obtuse cone, having both ends rounded, 11-16th of an inch in length, and 9-16th of an inch wide at its broadest part, and a quarter of an inch at its narrowest end. It is semi-cylindrical in shape, having its upper surface rounded in a line with its greatest length, the entire surface being covered with a profusion of very fine punctations. This tooth is exceedingly rare in the Coal Measures, but is said to be a moderately common form in the carboniferous limestone of Armagh, in Ireland.

Nos. 5 and 6 are two fine examples of *Petalodus*, obtained from the upper foot coal of the Lower Coal Measures, Oldham —for which I am indebted to the kindness of Mr. George Dearden, Ganes Bar, near that town. These teeth are the only two of this genus, derived from the Coal Measures, which have come under my observation (if, indeed, they are not the only ones yet found), although they are by no means rare in the carboniferous limestones of Ireland and Yorkshire. In confirmation of this, I may state state, that on these specimens being recently submitted to the Earl of Enniskillen, that astute and accomplished observer remarked that he had never previously met with teeth of this genus from the Coal Measures. The specimens measure one inch across the widest part, three-quarters of an inch in length, and half an inch across the base. They are convex on one side and flat on the other, and one of them shows traces of rather indistinct punctations on the upper or convex surface.

Nos. 7 and 8 are also two palatal teeth from the Lower Coal Measures of Oldham. No. 7 is doubtfully referred to the genus *Helodus;* its shape, however, is not that usually characterising teeth of this class. No. 8 is an undetermined palatal tooth of so unusual a form, that I have not ventured to offer an opinion as to the genus to which it should be referred.

Nos. 9 and 10 are two palatal teeth from the same locality and horizon as Nos. 5 and 6, described above, and probably belong to the genus *Helodus;* the form of which, however, is so different from that usually assumed by teeth of this genus, as to render this determination somewhat doubtful.

Mr. Plant said that one of the fine specimens of *Petalodus* which was now exhibited had been shown to him in 1865, when he made a drawing of it, and recognised it as a new species. He believed the genus *Petalodus* was included in

the list of Coal Measure fossils found in the North Staffordshire Coal Measures, which the late Mr. Salter compiled for the Memoir by the Geological Survey.

Mr. Alderman WILKINSON moved a vote of thanks to Mr. Aitken, which was seconded by Mr. DICKINSON, and carried.

GEOLOGY OF THE PARISH OF HALIFAX.

A communication from Mr. James Spencer was then read, entitled "The Third Part of the Description of the Millstone Grit Series of the Parish of Halifax, Yorkshire."

Since the publication of my first Paper on the Millstone Grit Rocks, fresh information has been obtained concerning the character and details of the Second and Third Grit series. It was impossible to realize, judging from mere external appearances, what a rich vein of geologic lore lay hermetically sealed in those strata.

The sinking of the shafts and the driving of the tunnel under Wadsworth Moor, for the Water Works, furnished me with much new information in connection with them. And the finding of rich beds of fossils has enabled me to link together many of the strata which before stood isolated. The bed of marine fossil shells, in one of the puddle dykes of the Castle Carr reservoirs, for instance, is now satisfactorily accounted for, and those strata proved to be in the shale upon the Third Grit series.

The fossiliferous bed met with during the construction of the tunnel between Sowerby Bridge and Luddenden Foot may be referred to the same series. Thus it often happens

in original scientific researches that the observation and careful study of new facts subsequently obtained lead to the solving of many problems and the correction of previous errors.

By the aid of these and other discoveries, all the strata which lie between the rough rock and the pebbly or Kinder Scout Grit can now be systematically arranged. These Second and Third Grit series, consisting of six different beds of grit and flagrock, separated by beds of shale, are now considered, geologically speaking, to be by far the most important members of the Millstone Grit rocks. Their great variety and extent, comprising sandstones both pebbly and fine grained, flagrocks, slates, compact grits, gannister-rock and seat-earths, coal-seams, together with coal-plants in the sandstones and shales, and also beds of shale, in a few localities containing marine remains in great abundance and in a good state of preservation.

In my division of the Grit Rocks, in the paper already referred to, I had mainly to rely upon lithological characters, but few strata bearing fossils having then been found. But now the case is different, I am acquainted with five or six different beds of marine fossil shells, three of them containing also fish remains. There are also two distinct beds with arenicolite markings—one in the middle of the second grit series and the other under the third grit, the markings in the upper bed being quite distinct from those in the lower.

In my second paper, "Additional Notes on the Millstone Grit Rocks of the Parish of Halifax," after showing that the Second Grit of the Geological Survey was merely the basement bed of the rough rock, I gave reasons for my opinion that the White Grit of Mixenden and Warley Moor

is the true Second Grit. And I endeavoured, on palæontological evidences, to separate it from the rocks below. But acting upon a hint from my friend Mr. John Aitken, F.G.S.,—that since these Grit rocks and the Yoredale strata below may be regarded as passage beds between the Mountain limestone and the Coal Measures, and seeing that most of the species of shells pass through them into the Coal Measures, and consequently, that fossils can afford no certain guide in the division of these Grit rocks.—I have now grouped together the Mixenden Grit and the four Grits below, which appear to form a natural lithological group, as they are placed in the sections at pages 206 and 208.

The Third Grit, as I before described, is the massive grit which forms such a conspicuous landmark along the middle of the eastern side of Calder Dale, from Pecket Well to Midgley. Hathershelf Scout, opposite Mytholmroyd Station, is also formed of this rock. It ranges throughout the whole of Luddenden Dale from Luddenden Foot, by Booth, to Castle Carr. It also forms a noticeable rock in Crag Dale and in the Rybourne Valley from Sowerby Bridge to above Ripponden. Throughout the whole of its course, it is characterised by having one or two thin seams of coal associated with it. The Geologists of the Geological Survey appear to have been greatly puzzled with this rock. They called it a Third grit in some places, and a Fourth grit in others, and make it jump about in the Survey Map most unaccountably, by means of those ubiquitous white lines, denoting faults. This Third grit is one of their Third grit series from Pecket Well to Midgley, there they make it take a clean jump out of existence and it is seen no more, but its place is supplied by the Fourth grit, from Luddenden Foot up to Booth and thence up as far as the Lodge at the

entrance to Castle Carr. I believe I have obtained clear evidence to prove that their supposed Fourth grit of Luddenden is really the Third grit in the natural and proper sequence of these Millstone Grit rocks.

In my first Paper I estimated the thicknesses of the four Grit rocks to be as follows :—

	Feet.	
1. Rough Rock	100	North-east of the Calder.
Shales	300	
2. Grey Grit..	80	
Shales .... 350 to	400	
3. Gannister Rock	100	
Blue Shales	450	
4. Pebbly Grit	120	
	1550	

The present arrangement as given below, slightly differs from the above, but this difference arises from grouping them differently, and from taking into account their increasing in thickness from south-east to north-west.

	Feet.	Feet.	
1. Rough Rock and Flagrock	130 to	150	North-east of the Calder.
Brown and Black Shales.	150 „	250	
2. Grit Series	550 „	600	
3. „	300 „	450	
4. „	250 „	300	
	1380 „	1750	

The following more detailed description will illustrate the character of the several divisions :—

The Second Grit.		Feet.
1st.	Warley Moor and Mixenden Grit	40
	Brown Shales	80
2nd.	Soft Sandstone	20
	Shale	30
3rd.	Thick-bedded Grit	50
	Shales	50
4th.	Vermiculite Beds	30
	Shales	40
5th.	Deep Clough Rock	60
	Shales	20
	Deep Clough Rock	20
	Grey Shales	120
	Total thickness	560

The Third Grit.		
1st.	Thick-bedded Pebbly Grit, with coal seams	80
	Shale..	50
2nd.	Booth Stone, with Arenicolites....	60
	Shales	150
		340

The Fourth Grit.		
1st.	Pebbly Grit of Pecket Well	50
	Slates and Shales....	50
2nd.	Pebbly Grit of Crimsworth Dean.... ..	150
		250

Having, when collecting materials for my papers on the "Millstone Grit Rocks," become well acquainted with the outcrops of the strata around Wadsworth Moor, I from the first took great interest in the operations carried on in the making of the tunnel through that hill. I made a section

of the various rocks, which I considered likely to be met with, in sinking the shafts and driving the tunnel. I paid numerous visits to the works, with the object of comparing the actual results, with my theoretical section. And it was with much satisfaction that I found them to agree in the main characters and thicknesses of the beds. But many new facts were also brought to light, which have been of great service, in aiding me in tracing the succession of the same strata in Luddenden Dale, and to correlate them with the same series in Calder Dale and in the Rybourne valley.

The Second Grit series is well exhibited along the upper part of the eastern side of Luddenden Dale, where it may be seen and examined in the natural sections formed by the cloughs leading up to the moor, the best exposure of the rocks being in Cat-i'th'-Well Clough.

The Third Grit occupies a great extent of Luddenden Dale, Calder Dale, and the valleys and moorlands south-west of the Calder.

VERTICAL SECTION,

SHOWING THE MILLSTONE GRIT ROCKS, 1700 FEET THICK—IN DESCENDING ORDER—FROM THE BASE OF THE LOWER COAL MEASURES TO THE TOP OF THE YOREDALE ROCKS.

THE FIRST OR UPPER GRIT SERIES, containing the Rough Rock and Flag Rock — total thickness, 350 feet.....	ROUGH ROCK. Blue Shale, Flag Rock, Shales (thick), *Fossiliferous Shale*, Shales (thick), Coal Seam (6 inches), Seat Clay, Shale.

THE SECOND GRIT SERIES, containing the Flag Rock group—total thickness, 550 to 600 feet.....	Cold Edge and Mixenden Rock, Shales (thick), *Fossiliferous Shale* (*thin*), Shale, Soft Sandstone, Shale, Rough Grit and Flagstone, Shale or Bind, *Arenicolite Beds*, Bind, Deep Clough and Midgeley Moor Flag Rock, Bind, Flag Rock, Bind, *Fossiliferous Shale*, Bind, Coal Seam (thin).

THE THIRD GRIT SERIES, containing Coal Seams and Fossiliferous Shales—total thickness, 300 to 450 feet.....	Rough Grit, Coal Seam (thin), Grit (thin), Coal Seam (thin), Bind, *Booth-stone*, *Arenicolite Beds*, Bind, Black Shale, *Fossiliferous Shale*, Cone-in-Cone Clay, Bind, White Rock, *Fossiliferous Shale*,	Thin Beds.

The Fourth Grit Series, containing the Kinder-scout Grit—250 to 300 feet, total thickness	Packet-Well Rock, top bed of Fourth Grit, Bind, Kinder-scout Grit or Pebbly Grit, base of the Millstone Grit Series.

The Yoredale Shales and Rocks.....	Seen in Horse Bridge Clough.
The Mountain Limestone..	Not found in the district.

Wadsworth Moor Tunnel (Lithographed Section No. 1.)

This Tunnel was made by the Halifax Corporation, for the purpose of connecting the new Reservoirs at Widdop with the Castle Carr conduit. The length of the Tunnel is about 2550 yards, and it lies at an elevation of 850 feet above the sea level, the highest part of the Moor above it, having an elevation of 1350 feet. There were three shafts sunk from the Moor to the Tunnel. The deepest, No. 2, being 476 feet in depth. No. 1, on the Castle Carr or easterly side, being 400 feet deep, and No. 3., near Pecket Well, having a depth of 384 feet. The course of the Tunnel is nearly due east and west, beginning at the western end in a clough, just below the Inn at Pecket Well, and emerging at the eastern end in another deep clough just below Castle Carr.

Out of 900 feet of strata composing the second and third Grit series, no less than 565 feet were gone through in the shafts and west end of the Tunnel. The following is the section of the rocks cut through in the central or deepest shaft—

			Feet.	in.
	1.	Peat or Moss ..	4	6
	2.	Sandstone	48	0
	3.	Blue Bind.. ..	81	0
	4.	Seat Earth.. ..	3	0
	5.	Grit and Flags..	57	0
	6.	Blue Bind ..	60	0
Highly charged with fossils *Goniatites*	7.	Black Shale ..	20	0
Aviculo-pecten, &c.	8.	Blue Bind.. ..	50	0
	9.	Seat Earth ..	6	0
	10.	Sandstone	42	9
	11.	Coal		2
	12.	Seat Earth.. ..	3	0
	13.	Blue Grit	28	0
	14.	Rock Bind ..	73	0
			476	5

In consequence of the strata dipping eastwards, still lower strata were penetrated in the most westerly or No. 3 shaft.

	Feet	ins.
To the bottom of No. 2 shaft as already stated	476	5
No. 3 shaft (below the above) Rockbind	35	0
Black Shale	20	0
Fossiliferous Blue Shale	7	0
Goniatites and Fish remains (*) Clay Ironstone	0	4
Cone in cone..	0	2
Gannister Seat Earth	4	6
Bottom of Shaft Bind..	6	0
Lower Strata on each side of the shaft, White Grit Rock	4	0
Goniatites *Aviculo-pecten* (†) Blue Shale	12	0
	565	5

(*) This is the stratum which yielded the interesting suite of Fish remains, described by Mr. John Aitken, F.G.S., in Vol. XIII., Part III., page 36, of this Society's transactions.

(†) This Shale rests immediately upon the upper bed of the Fourth Grit.

The Strata met with in the Shafts.

There was nothing very remarkable met with in No. 1 and No. 2 shafts, beyond what was seen in No. 3, the strata being pretty regular in the hill. A strong sandstone about 50 feet thick, and a bed of grey bind 81 feet in thickness were sunk through in each of them. These two beds were remarkably regular with a dip of about 3° to the east. There were also two other sandstones met with, but as these and their associated strata were also sunk through in No. 3 shaft, in order to avoid repetition I will confine my remarks to a description of the results therein obtained.

In sinking No. 3 shaft a bed of rock about 44 feet thick was passed through, then a bed of grey bind about 140 feet thick, in the middle of which there was a bed of shale about 30 feet thick. This black shale yielded a wonderful profusion and variety of fossil shells, there was a layer of about 3 or 4 feet in thickness which was literally full of *Aviculopecten*, *Modiola* and *Posidonomya* and flattened *Goniatites*. In this stratum there were also several layers of nodular concretions of iron-clay, which yielded the same species of fossils as the pecten shale, but in a more perfect state of preservation. I obtained about a score of species, such as *Goniatite*, *Nautilus*, *Orthoceras*, *Modiola*, *Posidonomya*, *and Aviculopecten*, some of the nodules being one mass of shells, a single one in some instances yielding hundreds of these shells, but generally small specimens. The second bed of sandstone met with was the Third Grit rock. It was of a very strong, massive character, full of pebbles. In the middle of it there was a band of coal of about two inches in thickness, having underneath it the usual bed of seat-earth. Below this grit, 108 feet of rock-bind was passed through, then a bed of shale 27 feet in thickness, and at the bottom of the shaft a bed of very hard mottled rock or

gannister was encountered, which was very full of portions of *Stigmaria*, and blackened with rootlets, but no coal was found upon it.

I had watched the progress of this shaft with great interest, and had paid frequent visits to it, when through enforced absence I was prevented from visiting the spot for several months—a circumstance which doubtless led to my not finding some of those beautiful specimens of fish, described by Mr. Aitken.

The Strata of the Tunnel.

At the west end of the tunnel the miners began to mine in a bed of shale just under the top bed of the Fourth Grit rock. But from the dip of the strata they soon had to face this massive rock, which had to be cut through. I had calculated that the tunnel would run in this rock to within a short distance of No. 3 shaft, but owing to the rock dipping very rapidly, they passed through it about half way between the entrance and the shaft. They then came upon a bed of dark blue shale about 12 feet in thickness, which contained a great quantity of marine shells, such as *Goniatites*, *Aviculo-pecten*, &c. It lay directly on the fourth Grit. I went into the tunnel and examined this layer of shale in *situ*. The dip, which had been very rapid from the entrance to within a short distance of the shale, gradually flattened out, until at length it was nearly horizontal, and the tunnel was carried through it for a considerable distance, the strata evidently lying in a shallow trough.

In approaching No. 3 shaft, the strata began to rise gradually and continued to do so until about midway between No. 3 and No. 2 shafts, where they dipped rapidly again eastward, from this point to a little beyond No. 1 shaft, the dip was very regular, being about one yard in eighteen.

It will be seen by referring to the section, that in consequence of the occurrence of these depressions in the rocks, the bed of fossiliferous shale was cut through for a considerable distance on each side of No. 3 shaft, consequently the greater portion of the shale excavated was brought to the surface by means of that shaft, and it was there where the fossil-fish remains previously referred to were found. A small portion was however brought up at No. 2 shaft, and a little also found its way to the west end of the tunnel.

The gannister rock in this shale was unusually full of *Stigmaria*, which were well preserved and the piths intact, in the centres of the stems. The rootlets radiating from them quite blackened the rock. There was every appearance of this being a true seat-earth, and yet no coal was found resting upon it. There were evidences that a bed of coal had been originally formed there, and that before the shale which now rest upon that rock was deposited the coal had been denuded away. There are many instances of this sort met with in the Grit rocks. In making these shafts, several beds of gannister and seat-earth were passed through, but no coal, except the thin seam in the middle of the Third Grit, was met with.

The gannister rock of Mount Skip above Wadsworth, with its two seams of coal, appears to be about the same horizon as this coal.

This rock appears to thicken out towards the south-west and to form an independent rock in Calderdale and in the Rybourne valley, the two seams of coal being continuous with it.

In all these shafts a bed of seat-earth was found resting upon the top of the Third Grit, but without any coal upon it. But at Midgley, and in various other places in Calder Dale and in Luddenden Dale a bed of coal of from 2 inches to 10

inches in thickness occurs upon it. In some places there are two seams separated by beds of shale and rag.

A little beyond No. 1 shaft a fault crosses the tunnel in a south-east and north-west direction, which uplifts the Third Grit about 100 feet to the north-east. The strata about here for a considerable distance being broken up into fragments. From this place a quantity of *Breccia*, composed of small angular fragments of Grit embedded in a matrix of red and grey sandy shale was brought out, the whole forming a compact mass, how this *Breccia* was formed, whether by the breaking up and subsequent consolidation of the rocks, by the same action which caused the fault, or whether it was formed when the beds themselves were being deposited, is difficult to determine. But from the fact of not much of it being met with and from its reddish colour, it appears very probable that it was formed in a line of fracture, and consolidated by the infiltration of the oxide of iron and lime. Another fact which appears to me to support this suggestion is, that numerous veins of *Marcasite* (white iron pyrites) were met with. This mineral seems to have been chiefly formed about the joints of the rocks. Small particles of *Galena* also occurred along with the *Marcasite*.

Nearer the east end of the tunnel, a thin vein of lead ore was met with in a narrow fissure in the rocks, and a little further on some of the rock-bind contained a larger percentage of lime than is usually found in the Grit rocks, which at the time, led to an impression that the Mountain Limestone had been reached. The difference between the Millstone Grits, and the Coal-Measures appears to me to be, that the former contain a larger per centage of lime and arenaceous matters, while the coal-strata contain a greater abundance of carbonaceous and argillaceous matter. The shales and bind brought out of the tunnel, and the shafts contained an abundance of

fragments of vegetable matter, being in some places quite blackened by it. I regard it as an evidence, that during the period when the grit rocks were forming the contiguous lands were covered by a luxuriant vegetation, and their decaying remains were carried with the floods into the shallow seas.

The Geology of Luddenden Dale.

In this beautiful dale, I have spent many of my leisure hours during the past summer, in thoroughly working out the order and connections of the various beds of grit and shale and in investigating their fossil contents. Nowhere else in all this extensive district of Grit rocks can there be seen in so small an area, a greater thickness and variety of rocks than are exposed along the eastern side of this valley. From Sentry hill down to Wade Wood bridge, all the grits and shales from the rough rock down to the Fourth Grit, or about 1400 feet of strata, may be seen exposed and can be practically examined. The lowest rock exposed being the upper bed of the Fourth Grit, which first makes its appearance in the beck at the bottom of Wade Wood. It rises gradually to the north up to the Spa Well, from whence it gradually falls and finally disappears under the overlying shales at Low Bridge, thus forming a gentle anticlinal axis.

The most conspicuous rock in the valley is the Third Grit rock, which extends from Luddenden Foot through Luddenden up to Booth. Before reaching this place it leaves the bed of the brook, and gradually rising encompasses the valley in a well defined belt, which following the sinuosities of the valley finally disappears above Castle Carr under the overlying strata. Lying between this rock and the Fourth Grit there are about 200 feet of rock-bind and shales.

Below the Third Grit at Booth, there is a peculiar thin-bedded grey rock, which is quarried for rough slating and

other building purposes. Some of the beds of Grit make very good grindstones. This rock is remarkable on account of the occurrence in it of numerous small trails of *Arenicolites*, some of the beds being quite covered with them. But there is also a peculiarity about some portions of this rock which is very characteristic. Many of the lower beds contain a small amount of lime with a larger percentage of iron, and are also divided by numerous joints into oblong blocks, which when split up into flags display around a centre of blue a series of red rings, which extend to the the outer margins of the stones.

The faces of the quarry at Booth presents quite a mural aspect, the ends of the blocks being moulded in a curious manner, and appear as if they had been wrought by a mason. Some of the beds yield an abundance of the common fossil plants—*Stigmaria, Sigillaria, Lepidodendra, Calamites, &c.* This rock and the shales below occupy the lower part of the valley from Booth to Castle Carr.

Above the Third Grit there are from 80 to 120 feet of shale and rock-bind, which are covered by another very important rock, which forms a second ridge all round the valley. It consists of a series of beds of grit and flags, and it is wrought in various places, both in this valley and in Calder Dale, for flags and building stone.

The average thickness of this rock is about 60 feet, but in some places there are two beds of stone divided by a bed of blue shale, and the two together, with the intervening shale, give a thickness of about 100 feet. To this rock I have given the name of the "Deep Clough and Midgley Moor Flag-rock." In the Deep Clough Quarry, opposite Castle Carr, there is a bed of rag of about four feet in thickness, which is also very rich in fossil plants.

Overlying the Deep Clough Stone there are about 50 feet

of shales, and resting upon them there occurs one of the most striking rocks in the Second Grit series. It is a thin-bedded, bluish grey grit of about 30 to 40 feet in thickness. The layers vary from the eighth of an inch to four or five inches. The thicker layers are wrought for grindstones, for which purpose they are well adapted. But their chief peculiarity consists in the vast abundance of worm tracks or *Arenicolites* with which their surfaces are covered. This rock extends over a wide area. I have traced it from Cat-i'th'-Well Clough to Deep Clough, and from thence to Bare Clough, above Castle Carr, where those characteristic markings occur in great abundance.

An excellent section is to be seen on the other side of the moor, in the Grindstone Quarry, near Dyke Nook, in Higher Oxenhope, of which the following is the order:—

		Feet.	Inches.
1. Gannister Rock, full of fossils		1	6
2. Raggy Stone..		8	0
3. Flagstone		2	0
4. Blue Grindstone	with *Arenicolites*	4	0
5. Thin Plates ..		20	0
		35	6

There the stones, which lay scattered about the quarries in all directions, were so densely crowded by these worm tracks, that they resembled so many slabs covered with cuniform inscriptions, but these hieroglyphics of nature, relate to us a chapter of the world's history of the period when these beds were forming as truthful, if not more so, as any related by the hieroglyphics on the ancient monuments of Assyria.

They tell us that during the time these beds were forming, the waters at this place must have been in a quiescent state,

and that myriads of marine worms lived and died, generation after generation, on the very spot where we now find their fossilized remains.

These thin Grit beds are covered by a bed of shale, and upon that there occurs a thick-bedded grit of about 50 feet in thickness. Overlying this there is another bed of shale, which is crowned by a soft yellow sandstone, having a bed of gannister rock upon it, this rock, though not more than about 20 or 30 feet in thickness, appears to be co-extensive with the thin Grit beds in this district.

Resting upon this rock, there are from 80 to 100 feet of shales, having towards the bottom a bed of seat earth, with a thin seam of coal upon it. A little above the coal there is a thin layer of black shale, containing *Goniatites* and *Aviculopectens*. Upon these shales reposes the uppermost bed of the Second Grit series, which is the massive grey Grit of Cold Edge and Mixenden.

The Millstone Grit rocks have been described as being deposited in a turbulent epoch. Some of the Grits may have been produced along the shores of rough and stormy seas, but by far the greater portion of them in this locality bear unmistakeable evidence of having been deposited in a quiet, regular, and uniform manner. So far from these rocks having been formed in the spasmodic manner related in some text books, if there is one fact, which stands more prominently forward than another, it is this, that judging from the hardness of materials which compose them, and the regularity which marks the beds of bind and shale, together with the very fine grained character of many of the beds of Grit, they must have been even more slowly deposited than the later Coal-Measures themselves, which are generally acknowledged to have been formed in a very slow manner. Another fact which supports this idea is the great

number of seat earths and gannister beds which occur in them, indicating so many ancient land surfaces, and also the many distinct beds of marine remains, as plainly indicating so many ancient sea bottoms. These facts appear to directly prove that these strata were formed under conditions similar to the coal strata, namely, in an area that was sinking slowly beneath the waters, but oscillations of level occasionally took place, and the area was alternately land and sea over and over again.

There is no evidence in this locality to show that these changes were brought about by sudden catastrophes, but on the contrary, all the strata tend to prove that they took place so gradually that none of the deposits were much affected by them. I regard these rocks, with the Yoredale rocks, as forming a series of passage beds between the mountain limestone on the one hand and the Coal-Measures on the other, being connected by their fauna to the former and by their flora to the latter.

In conclusion, I trust that it has been satisfactorily demonstrated in the discription here given of the Millstone Grit Rocks, that they are by no means so devoid of interest as they have hitherto been supposed to be, and that the life of the period was much more varied and continuous than was formerly imagined. The great abundance of the plant remains diffused throughout the Grit rocks, proving that while the seas teemed with animal life, the contiguous lands were clothed with perennial verdure.

A vote of thanks to Mr. Spencer was passed on the motion of Mr. Martin, seconded by Mr. Aitken.

Mr. Aitken said: It affords me pleasure to bear testimony to the truthfulness with which these rocks are

described, and the great amount of labour which has been expended in working out the details of the Paper. Mr. Spencer is a most indefatigable worker, a close observer and an accurate recorder of whatever comes under his observation. His time, for several years past, has been devoted to an examination of the various sections which the Millstone Grit rocks exhibit in the neighbourhood of Halifax; and we have, in the three Papers read to this Society, the collective results of his labour. I have been over a considerable portion of this ground with Mr. Spencer, and am satisfied that the description he has given is in every respect worthy of confidence as an accurate description of the Geology of the district. There is one portion of the Paper to which I would refer for a moment, where Mr. Spencer describes the fault discovered in driving the tunnel through the Wadsworth Moor. In that fault he mentions the finding of a peculiar kind of *Breccia*. I have examined specimens of this *Breccia*, which are remarkable for containing angular pieces of Grit rock,—some of very considerable size—which seem to be set in a matrix of a reddish arenacous character, but forming one compact and concrete mass, as though it were the original constitution of the stone. The mode in which this could have been formed seems to be a difficulty with Mr. Spencer to understand, and I am equally at a loss to account for it. If we consider that these stones were crushed up at the time when the fault was formed, it seems difficult to account for their having been cemented together again by the matrix, which does not contain a very large proportion of lime—although that mineral is present—nor is there iron present in sufficient quantity to have acted as a cement; yet, the fragments of Grit have been formed into a solid mass in a very remarkable manner. This is open to the observation of any gentleman who may visit the locality.

Mr. Spencer also mentions the occurrence of a large quantity of *Marcasite*. This is a crystallised sulphuret of iron (white iron Pyrites) and is spread in a peculiar manner over the vertical surfaces of the stones in this fault in conjunction with *Pearlspar* or *Dolomite*, which also covers the surfaces of the stones and presents a glistening aspect. Besides *Marcasite* we found crystals of blende and traces of lead and other metals. I possess specimens of all these, from this particular locality, and some of them are most interesting and beautiful. Some time ago I sent specimens to the British Museum, where they are now exhibited. I think Mr. Spencer has fallen into one slight error. He describes these as occurring in veins. They do not occur in veins, but upon the vertical surfaces of the stones, in the neighbourhood of the fault, no doubt having been deposited there in the crystalline form during the irruption of steam or hot water from the interior of the earth, through this line of weakness. I have been greatly pleased with the Paper, and shall be glad to see it printed, with the accompanying tunnel section in the Transactions of the Society.

The CHAIRMAN: It would be certainly necessary to publish the two sections to illustrate the Paper.

Mr. AITKEN: It is valuable because made from actual measurements taken during the sinking of the shafts; and I think great praise is due to Mr. Spencer for having devoted so much time, during the progress of the work, to verify every part for himself. The sections may be relied on, therefore, as accurate in all their details.

Mr. PLANT: I fully concur in all that Mr. Aitken has said about the thoroughness of the labour undergone by Mr. Spencer. It is the more valuable because the work is independent, and Mr. Spencer is an original worker in all respects.

He has not quoted anything from authorities, nor, in fact, does he appear to be acquainted with the existing literature of the geology of the district in which he resides, and over which he has worked so zealously; perhaps, had he been so, he would have seen reasons for not speaking so strongly against the conclusions arrived at by the geologists upon the Geological Survey. His labour is so purely local that it cannot fail to be valuable, from the carefulness with which he has gone into the whole details; and I regard his having plotted, so to speak, the horizons of these fossiliferous beds as an important addition to our knowledge of the structure of the Millstone Grit formation. But the Millstone Grit itself is one of the most difficult portions of the geology of the great Carboniferous formation. For years it seems to have been a matter of very great difficulty with the Survey to define its broad boundaries. It has, however, been decided pretty emphatically, by almost all the leading authorities, that the Kinderscout grit is the base of the true Millstone Grit series, and that the Rough rock, wherever it occurs, is the uppermost bed; but between these two horizons lies a varying field, upon which there has been found no limit to the varieties of details according to the locality in which particular observers have been working.

Now, Mr. Spencer has spoken a little too slightingly of the labours of the gentlemen of the Geological Survey, in the district over which he has himself worked. It may be that he has seen with different eyes, and relegated several of these Grit-stone beds to positions which, to him, may appear to be more accurate and better defined than those laid down by the Geological Survey; but if he had had the wider experience of gentlemen like Mr. Hull, Mr. Green, Mr. Ward, and others connected with the Survey—who have had the advantage of tracking the Millstone Grits from their

commencement near Ashby-de-la-Zouch in the south, up to their termination in the Scotch coal fields—he would have seen that there was no possibility of deciding and always harmonizing the true position of the intermediate beds. Mr. Hull confesses that this difficulty is so great in Derbyshire and South Yorkshire, that they have been obliged to make five divisional beds of Grit, whereas Mr. Spencer will allow only four.

Besides, it has been laid down, as a convenient theory which has been to a great extent proved by observations, with regard to the Millstone Grit, that whilst up in the north it continues to thicken until it reaches the enormous depth of 2,800 feet, in the south it becomes almost wasted away, appearing in thin beds, which lose all their normal character, and are only to be detected as Millstone Grits by their positions between the Yoredale rocks below and the Coal Measures above, having lost everything but their horizon in the Carboniferous system. Mr. Hull's division of these Millstone Grits in Staffordshire, Cheshire, Lancashire, and along the borders of the Pennine ridge, are not wholly in accordance with that of Mr. Spencer, as exhibited in his vertical section, but there is no great reason to doubt that both are in their local aspects correct, regard being had to the fact that different localities are referred to, any general deductions, such as Mr. Spencer has attempted, with regard to the constant position of any one of these Grits, have baffled higher and better authorities.

Mr. Spencer must be unacquainted with the most important work which treats of the Geology bordering upon his own locality.* If he had been so, I dare say it would have facilitated much of his own detailed

* Geology of North Derbyshire and Yorkshire, by Messrs. Green, Foster, & Dakyns. (Memoirs of Geo. Survey.) 1869.

labour, and at least would have given him the reasons for the separation of the different beds of Grit which the gentlemen of the Survey have seen proper to lay down. At the same time, we are very much obliged to Mr. Spencer for having given us so many new details respecting a locality which, if not quite belonging to Lancashire, is only just over the Pennine ridge; and, as Mr. Hull says, "the Geology of the south-western flank of the Pennine ridge and that of the north-eastern flank are very much the same in their broad features." It is only a question of detail as to how far the beds are bare, expanded, or diminished, or changed from their normal aspect.

Mr. Aitken: I think Mr. Plant misapprehends Mr. Spencer's division of the Grit rock, into four "beds." That division has reference simply to the No. 2 bed. If you take the whole series throughout you will find 13 beds described by Mr. Spencer.

Mr. Plant: I was referring to the enlarged section where he makes four broad divisions—first, second, third and fourth grits. The Survey shows no fewer than five bread divisions of the same beds comprised between the Kinderscout grit at the bottom, and the Rough rock at the top.

Mr. Aitken: As far as I understand the division of the Geological Survey, they make only four beds: the Rough rock, the flag rock, the No. 3 rock, and the Kinderscout Grit. Mr. Spencer, on the contrary, takes the two first divisions of the Geological Survey, joins them together, and calls them the first Grit. Then, he has five divisions in his second Grit, three or four in the third, and two I think in the fourth; so that he has the same divisions, but groups them differently from the Geological Survey. As far as I know the Survey do not accept five divisions by name, but only four; conse-

quently there is no difference in that respect. I admit that the Geological Survey say, and properly so, that in some of their divisions, instead of there being one bed of Grit rock, there are two and sometimes three; still they call it by one name—No. 2, or No. 3, as the case may be.

Mr. PLANT: I think we perfectly agree in that respect, that it is only the division of rocks which occur between the Rough rock and the Kinder-scout grit. The Survey have thought proper to lay down five distinct broad beds, which, they say, are horizons, that mark the progressive formation of the Millstone Grit. Mr. Spencer claims not only that there are only four, but he also claims to have made an alteration in number 2, which, I think, does not at all accord with the Survey's division.

SPECIMENS EXHIBITED.

Ten fish remains of teeth from the Coal Measures, by Mr. John Aitken, F.G.S.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART VIII. VOL. XIII. SESSION 1874-5.

At the ORDINARY MEETING of the Society, held at the Rooms of the Literary and Philosophical Society, on January 26th, 1875.

Professor W. BOYD DAWKINS, F.R.S., President, in the Chair.

A list of Donations was read, of their current publications, from the London Geological Society, the Liverpool Geological Society, the South Wales Institute of Engineers, the Manchester Philosophical Society, and the Dundee Free Library.

The following gentlemen were elected ordinary members of the Society, Mr. Joseph Jackson, M.I.C.E.; Mr. Abraham Burrows, Bolton; Mr. Ralph Fletcher, jun., Bolton.

TERTIARY COALS.

Mr. A. W. WATERS, F.G.S., exhibited some specimens of Coals and Peats from the Alps and other places. He said, the specimens of Carbonised Peat he found in Northern Italy, under rather peculiar circumstances. The peat was on a mountain side—on a slope of twenty or thirty degrees—covered by mountain *debris*, and very considerably carbonized; but it was not so much changed as the lignites he exhibited from the older tertiaries (the Eocene and Me-

iocene)—and could not be older than the Pleiocene. Unfortunately, there was nothing to prove its date; he could find neither fossils nor plants; but it could not be older than the Pleiocene, because the elevation of that part had taken place since the Meiocene, and its state showed that it was not very recent. There must, of course, have been some break in the conditions, and it seemed to him extremely probable that this was an inter-glacial carbonised peat. It resembled in many respects the inter-glacial lignite from Switzerland, being quite soft and requiring to be dried before use. It would be well worth examining on the Alps, further, with a view to the discovery of plants, proving that in Italy there were further deposits of the inter-glacial lignite, under such conditions. Italian geologists considered some of the lignites there to be inter-glacial, but none had been clearly proved to be so. His object in introducing the matter was to induce any who might be in that quarter to make further investigations. He had also, on the table, specimens of Eocene and Meiocene Coal from the Alps and elsewhere. Some were from Bavaria and Switzerland. They were all very similar, and more resembled ordinary coal than many people in England were aware of. Some of the mines were of considerable extent, employing from 200 to 300 workmen; but near Lake Garda, where he obtained this carbonised peat, the quantities were ridiculously small for which they thought it worth while working. The proprietor of this "mine" told him that they got about half a ton per day with three men.

The President asked Mr. Waters if he had ever compared these with any of the Dürnten fossils.

Mr. Waters said he had a specimen of wood from the Dürnten mines—which he had visited,—and found it, in some respects, very similar. On the occasion of his visit,

he saw the black band, but was not aware that he had come upon the coal. It was quite soft, and he could drive his hammer into it, as he could into the surrounding clay, and except for the colour, he had no idea, at first, that it was the coal. When brought out, it had to be dried, as before described, after which it was capable of being split up.

The PRESIDENT. Certainly, the carboniferous deposits around the Alps are very different from the ideas generally entertained of such deposits in Lancashire.

Mr. WATERS said the greatest deposits of tertiary lignites were in Bavaria, where there were several considerable mines.

Mr. PLANT said it seemed to him that one of the specimens was much more like a bright jet, equivalent to the jet of Whitby, in the lias. It looked as fine as any of the Lancashire cannel coals. The specimen from Bavaria was much like the Lancashire bituminous coal.

The PRESIDENT: You were not able to make any cross section about this lignite, or find out whether there was any boulder clay about, or any glacial *debris?*

Mr. WATERS said he observed nothing that he could make out to be glacial. There was clay in association, but he saw no proof of its being glacial.

THE GEOLOGY OF HALIFAX.

Mr. AITKEN said that, in the Paper by Mr. Spencer, read at the previous meeting, on the Geology of Halifax, reference was made to a body of very peculiar *Breccia*, and certain minerals, which had been met with in driving a tunnel through Wadsworth Moor, for the purpose of conveying water to the town of Halifax. Having visited the spot, and collected minerals and specimens of the *Breccia*,

in question, he had brought them for inspection by the meeting. (The specimens were exhibited, and the peculiarity of the *Breccia*, as described at the previous meeting, were pointed out.) The other specimens, Mr. Aitken said, represented the vertical joints of the rock, upon which a coating of pearlspar had been deposited. Upon the pearlspar crystals of marcasite, sulphuret of iron, and sulphuret of zinc had been formed; and in one instance there appeared to be also *Galena*. These were very curious, as occurring in the Millstone Grit; for, so far as he knew, in this neighbourhood, these rocks had not yielded the minerals in question—at all events, not in the state in which they were found in this particular instance.

NOTE TO THE INAUGURAL ADDRESS,

By the President.

Professor Dawkins said: In quoting Professor Ramsay's views as to the Meiocene Geography, in my Address, page 193, the term *Rhine* is applied to the Meiocene river into which the tributaries fell that drained the area now drained by the Upper Rhine, south of Mainz.* He objects to such an application of the term. The conclusion also that this river debouched into the Mediterranean area, for which, I only am responsible, is so printed, that it may seem to bear the impress of Professor Ramsay's authority. It is based on the distribution of the Meiocene strata in *Dumont's* "*Carte Geologique de l'Europe,*" and on a study of *Professor Heer's* "*Le Monde Primatif en Suisse;*" in both of which authorities the Meiocene strata are traceable, sweeping in a broad band, through south-eastern France down to the Mediterranean basin.

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* Q. J. G. Soc. Lon. vol. xxx., p. 87.

The following Paper, communicated through Mr. J. Plant, Hon. Sec., was then read :—

THE HÆMATITE DEPOSITS OF WHITEHAVEN AND FURNESS.

By J. D. Kendall, C. and M.E., F.G.S.

The great revolution that has taken place in the manufacture of iron during the last few years, by the discovery of the Bessemer process, and the remarkable adaptability of the hæmatite found in the districts of Furness and Whitehaven for that process, has resulted in converting two remote parts of the kingdom, once almost exclusively devoted to agriculture, into districts whose most prominent features are their "mines and miners," and which, from their former comparative insignificance, have been raised, as if by magic, within a very few years, to a first importance in the iron trade of this country.

Although it will not be possible within the limits of a paper like this to describe at any very great length all the various facts that have been laid bare by the working of these deposits, from their first discovery up to the present time, yet it is hoped, by a system of condensing, that it will be possible to include the most important of them, so as to give as fair an idea of the position and character of these enormous deposits as it is possible to get without actual examination. An attempt will also be made to account for their origin, and also to assign to them their probable age. In order that these things may be rendered more clear, and the arguments by which the various conclusions are arrived at, followed more closely, it will be necessary in the first place to sketch out a brief outline of the geology of the two districts, and in doing that it will be as well, perhaps, to glance at the geology of another district, which is intimately

associated with them, and on the borders of which they lie. I refer to the English lake country. That district, as many are aware, consists almost wholly of a mass of rocks of Silurian age, out of which, by elevation and denudation, have been formed those wild, majestic, and towering mountains that now raise their bald and blackened summits to the sun as in defiance of time and all its mighty agencies, and yet they are, in reality, but the emblems of change and decay, the remnants of a past existence.

Around these rocks of the lake country, and resting upon an inferior continuation of them, there is an almost continuous band of Carboniferous rocks, varying in width from half-a-mile to about five miles, and which, in its course, passes through both the districts of Whitehaven and Furness. In their fullest development, the rocks forming this band consist of three formations—the Carboniferous limestone, the Millstone Grit, and the Coal Measures. Only in one part of the band, however, do the whole three formations appear together, and that is at Whitehaven, the remainder of it consisting chiefly of Carboniferous limestone, with here and there a capping of Yoredale rocks or Millstone Grit. The Yoredale rocks appear in Furness and terminate the Carboniferous group in that district, so far as is yet known. Everywhere the dip of this Carboniferous band is normal to its direction and outwards from the enclosed Silurians—that is to say, at Whitehaven, on the west side of the lake district, the Carboniferous rocks dip west; at Hesket Newmarket, on the north, they dip north ; in Furness, on the south of the Silurian mass, the dip is to the south, and at Shap on the east, they dip to the east. This radial nature of the dips has evidently resulted from an elevation of the underlying and enclosed Silurians subsequently to the deposition of the Carboniferous rocks. One of the chief effects of that elevation is that it has so tilted the outlying Carboniferous rocks that now, after

a part of them have been removed by denudation, the different formations thereof appear on the surface in a number of broken minor bands which, like the main one, run more or less completely round the slaty rocks of the Lake country, the newest formation being, of course, most to the dip, or farthest from the centre. On the outside of this Carboniferous band, there is another and similar band, which also passes through both the districts of Whitehaven and Furness, but which is made up entirely of Permian rocks. They rest unconformably on the Carboniferous rocks, and consist chiefly of red sandstones. With the lower portion of these sandstones there are intercalated two or three thick beds of *Breccia*, and in the centre of the system a thin band of magnesian limestone is sometimes found. Like the Carboniferous rocks, these different formations of the Permian system do not all appear together throughout the whole band, one or two of them being frequently wanting. For instance, at Whitehaven there is only a thin band of *Breccia* representing the lower Permian. Above that there is a band of magnesian limestone representing the middle Permian, and, finally, the upper Permian sandstone of St. Bees. In Furness, there is only the Magnesian Limestone and the Upper Red Sandstone, the lower Permian being entirely absent. These rocks have the same sort of radial dip as the Carboniferous rocks have, but the two sets do not correspond at all, either in direction or amount.

From the preceding I think it will be evident that, if we take a section through each of the two particular districts under notice, on the line of dip, that is, on an east and west line at Whitehaven, and on a north and south line in Furness, we shall have in each the following ascending order of rock systems. First, the Silurians, forming the base of both districts; then, resting upon those, the Carboniferous rocks;

and, lastly, the Permians. The formations making up these systems are also very much alike.

This great resemblance in the geology of the two districts, of course, follows from the fact I have tried to point out, that the geological character of both is the result of a similar set of changes which appear to have affected a very large area round about the English Lake Country.

Having now glanced at the geology of the two districts, I will proceed to the main object of the paper, the consideration of their hæmatite deposits. In treating the subject, it is proposed to divide it into four parts. First, as to the form and geological position of the deposits: secondly, their internal nature; thirdly, their origin; and, lastly, their age.

Form and Geological Position.

All the Hæmatite of these districts is obtained either from the Silurians or from rocks of Carboniferous age. The latter deposits are, however, by far the most important, the ore found in the Silurian rocks being so very limited in quantity as scarcely to be worth working.

(*a.*) *Deposits in the Silurians.*—The ore occurs in these rocks in the form of veins, of which there are a great number. Most of them, however, are but a few inches wide on an average, and are consequently not worth working. The only deposit yet found in them of any importance is in the Skiddaw slates, at Knockmurton, where several veins are now being worked that have an average width of 3 to 4 feet. Like most other veins, their width is by no means uniform. Sometimes they only show a few inches of ore; at others they are 9 or 10 feet wide, and nearly all ore. They do not maintain this width long, however, but nip in again to 2 or 3 feet. The ore is of excellent quality, but liable to become mixed, in the process of extraction, with various foreign substances that lie along with it. The direction of the lodes

is generally either N. by E. and S. by W., or N.W. by S. E., with a dip of from 45° to 80° with the horizon. These directions, I may remark, correspond exactly with those of the two sets of divisional planes intersecting the rocks in which the veins occur. This being the case, it would appear as if the veins and divisional planes were the result of one and the same great cause, the one being but an extension or modification of the other. Probably the veins are but opened divisional planes, having been so opened by some great elevatory strain.

(*b.*) *Deposits in the Carboniferous rocks.* (1.) Of the Carboniferous deposits a thin band occurs at Millyeat, near Whitehaven, at the top of the Coal measures there, but it is not of much value, being too thin (only about eight inches thick) and too much broken by faults to pay for working. It was tried some years ago, but soon given up, on account of the small quantity and the difficulty attending the getting of it. The quality of the ore is excellent, and but for the very small quantity there is of it, would, no doubt, have been worked more extensively than it has. The following is an analysis thereof made by Dr. Penny :—

Peroxide of Iron	97·85
Phosphate	·71
Silica	1·44
Lime	trace.
	100·00
Metallic Iron.....	68·5

(2.) The rest of the deposits are in the Carboniferous or Mountain limestone, and it is to them that I now wish particularly to direct attention.

The Carboniferous limestone series as developed in the two districts is very much alike, and consists mainly of alterna-

tions of limestone, shale, and sandstone. The sandstone and shaly beds are generally very thin, often not more than two or three feet in thickness, and sometimes less, but seldom exceeding 12 feet. On the other hand, the limestone occurs in huge masses, from 20 to 200 feet thick, and sometimes it is as much as 300 feet. It is in these thick beds of limestone that the hæmatite is found, sometimes filling fissures and lake-like hollows in that rock, just below the drift; and at others presenting itself in an irregular cavern-like form, deep down in the limestone. It does not appear to prefer any particular bed of limestone, as it is found in almost every bed from the lowest, resting on the Silurians to the highest, forming the base of the Grits and Yoredale rocks, respectively at Whitehaven and in Furness.

From the foregoing it appears that there is a very wide difference in the *geological* level of the deposits. Owing, however, to the tilted position of the limestone and the extent to which it has been denuded, this difference in *geological* level does not affect their *absolute* level, many of the deposits found in the lower beds being much nearer to the surface than those in the higher, as we shall presently see.

1. *Deposits in the Top Beds.*—At Whitehaven, in the upper beds of limestone, that is those lying immediately below the Grits, some of the finest deposits in the district have been found; as, for instance, those at Bigrigg, Crowgarth, and Parkside. At each of these places, the ore occurs in large irregular cavern-like masses in the Limestone, just under the Millstone Grit, one of the sandy or shaly beds of which forms the roof of the different deposits. Viewed in section, these deposits present somewhat the appearance of a bed, as they have exactly the same dip as the rocks in which they are lying, and generally preserve a very uniform thickness, which varies in the different deposits from 4 to about 40 feet.

Sometimes the Sandstone roof and Limestone floor are nearly parallel for as much as 100 yards, and they are so even for twice that length at Parkside. The following sketch (fig. 1) is a vertical section of that deposit taken on the line of dip and rise.

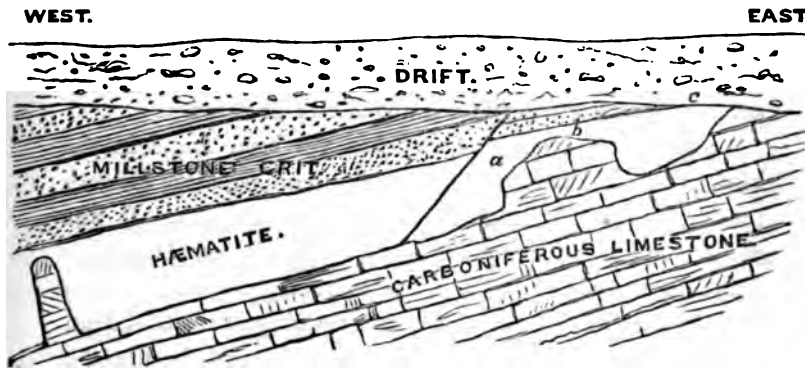

Fig. 1.

In the above sketch there is also a striking example of the way in which these deposits sometimes vary in thickness. At one place (*a*, Fig. 1) the ore is as much as 65 ft. thick, and only a few yards from that point (*b*, Fig. 1) it is not more than 3 or 4 feet. These variations in thickness are always caused by irregularities in the Limestone floor, the roof invariably forming a regular, even plane, which has exactly the same dip as the strata surrounding the ore. The thickening and thinning of the ore in this way gives rise to what are known by the miners as "rolls." In some deposits they are very abundant, and are frequently of great length. Their direction generally corresponds with the strike of the strata.

Few of these deposits, that occur just below the Grits, are found to be very far in from the rise edge of those rocks; in fact, in many cases the ore comes out from beneath them up to the drift, as shown at *c*, fig. 1. The inclination of the

strata, however, being somewhat high (about 15 degs.), the ore as it extends to the dip soon becomes covered by a considerable thickness of rocks, as at No. 4 Pit High-house, where the ore was found beneath about 60 fathoms of grits. It is also found in other parts of the district, beneath a thickness of rocks quite as great as that.

The superficial extent of many of these upper deposits is very large, that at Parkside covering an area of about 18 acres. The others vary from about 2 to 10 acres.

In Furness only one deposit has yet been found in the highest bed of Limestone, that is, lying immediately beneath the Yoredale rocks, and that deposit is at Stank. It was discovered about three years ago by the Barrow Hæmatite Iron and Steel Company, when searching for coal; but so little has, as yet, been done towards opening it out that I am not in a position to say whether or not it is exactly like the deposits in a similar position at Whitehaven. From the great resemblance of the Yoredale rocks to the Coal Measures it was for a long time thought by the Furness people that they contained coal; in fact, that they were the true coal measures. Several attempts were made, accordingly, to prove this. The first trial was made more than sixty years ago. From that time up to within the last four or five years nothing was done of any importance towards the settlement of this coal question. The Barrow Hæmatite Iron and Steel Co. then took it up, and commenced to sink a shaft at Stank, or rather they deepened a shaft already sunk, for there was in existence there an old shaft, which had been sunk to about 20 fathoms for over sixty years. They availed themselves of this, and deepened it to about 65 fathoms, when they came upon the Mountain Limestone. They then, of course, gave up all hopes of finding coal there. But something (I believe it was the redness of the Limestone) induced them to sink a few fathoms farther, and in doing so, at

about 95 fathoms, they came upon a splendid deposit of Hæmatite. This unexpected discovery was an era in Hæmatite Mining, and has opened up a field of search for iron ore in which it would have been considered madness to have looked for it before. Probably in the course of a few years there may be as many deposits working in the upper beds of Limestone in Furness as there are now in Whitehaven.

2. *Deposits in the Lower Beds.*—Coming now to the lower beds of Limestone, or those resting on the Silurian Rocks, we find some of the finest deposits in Furness, amongst which are those of Park and Lindal Moor, the first of which covers an area of about 15 acres, and has been proved at one point to be over 300 feet deep. The Lindal Moor deposit is also very large, being nearly 900 yards long and about 23 yards wide.

One or two very fine deposits also occur in the lower beds of Limestone at Whitehaven; as at Todholes and Messrs. Bain and Patterson's new pit at Woodend.

These lower deposits occur mainly in dishes or hollows in the Limestone, just below the drift and close up to the Silurians. Frequently they rest against those rocks on one side, as shown in fig. 2.

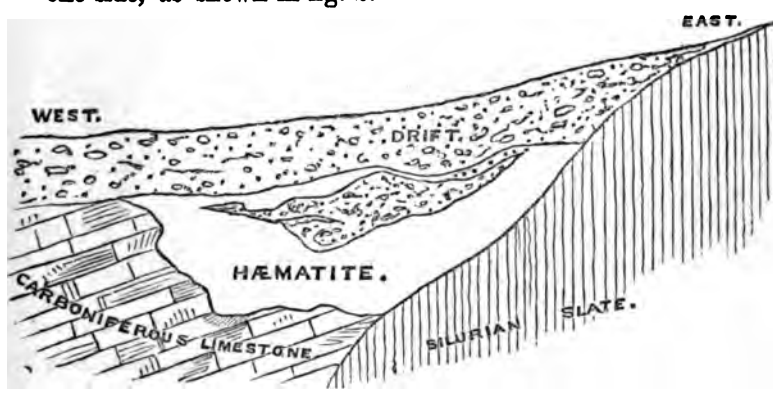

Fig. 2.

Both the Park and Lindal Moor deposits rest against the Silurians on one side, as in fig. 2, as also do the Todholes and Woodend deposits. It is believed by many that the deposits have a preference for this position, that is, between the slate and limestone. It certainly is not so at Whitehaven, for there are only the two deposits I have mentioned in that position altogether. In Furness there certainly are more in that position than at Whitehaven, but still not so many as to lead any one to the conclusion that the ore preferred to be there. Not a tenth of the deposits in that district are found in that position.

At Martin, in Furness, there is one of these deposits in the lower beds (see fig. 2), which, owing to the manner in which it is worked, is specially interesting, and may be taken as a good example of deposits in its position. When first discovered it was lying beneath a covering of drift about 30 feet thick. This has, however, all been removed, and the ore is now being worked like a quarry, so that there is a good opportunity of examining it thoroughly and ascertaining its exact form and character. It lies just on the rise edge of the limestone, by which it is surrounded on all sides except one, and that is formed by the underlying Silurians as they rise out at a high angle from below the Limestone. The length of the deposit is about 260 feet, and its width about 200 feet. The greatest depth has not yet been proved, but it is certainly over 50 feet. As it will be necessary to refer to the deposit again when considering the character of the ore found in the different geological positions, I shall not enter into any further description of it at present, but pass on to those deposits found in the intermediate beds of limestone.

3. *Deposits in the Intermediate Beds.*—These are both many and various. Some of them, especially those in Fur-

ness, lie immediately beneath the drift, in fissures and lake-like basins in the Limestone, similar to those in the lower beds. Others, mostly at Whitehaven, are at some distance down in the limestone, sometimes as much as 35 fathoms, and present an irregular cavern-like form, that is entirely surrounded by rock. Occasionally one of the bands of Sandstone or shale, which alternate with the limestone, forms either the roof or the sole in these deep deposits in the Whitehaven district, in which case the ore generally has the same dip as the strata in which it is lying, like the deposits have just under the grits; whereas when it is wholly surrounded by limestone it may dip any way, often just opposite to the planes of stratification. Good examples of filled fissures and lake-like deposits in the intermediate beds of the Whitehaven district, may be seen at the open works of the Crossfield Iron Company, (fig. 3); as well as at those of Mr. Sterling and Mr. Ainsworth. They are about the only deposits of the kind in the district.

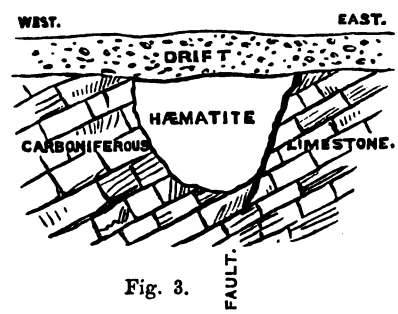

Fig. 3.

In Furness there are a great number of those shallow basin-like deposits, in fact, all the deposits in that district, with a few exceptions, are of that description. Amongst the most important of them may be mentioned Lindal Cote, Ure Pits, Askam, and Crossgates. Of the deep-seated deposits, peculiar to the Whitehaven district, a fine example may be

seen in the Salter and Eskett Company's No. 3 pit (*a* fig. 4.) The deposit worked by the Crossfield Company, in their No. 3 pit, is of that description, and there are many others beside.

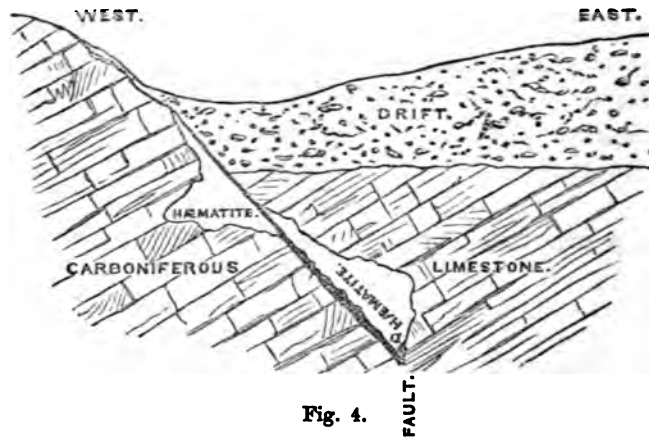

Fig. 4.

I am not aware that there are any of these deep deposits in Furness, at least any that are of importance, the majority of the deposits found in the intermediate beds of that district being, as I have just said, situate immediately below the drift.

4. *Features common to the Deposits in general.*—Hitherto I have spoken only of features that are *peculiar* to the different deposits. I shall now attempt to describe some of their more *common characteristics*, and first, perhaps, in importance, is the well-established fact that, wherever these deposits occur, whether just below the Grits, or down upon the Slate, or in the middle of the limestone series, their longest axis almost invariably corresponds with the Magnetic Meridian, or, to be more accurate, they bear about 5 degs. west of north in the Whitehaven district, and about 20 degs. west of north in Furness. (Figs. 5 and 6.)

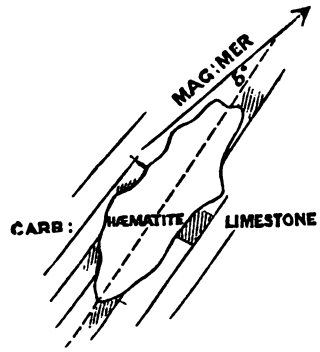

Fig. 5. (Whitehaven Deposits.)

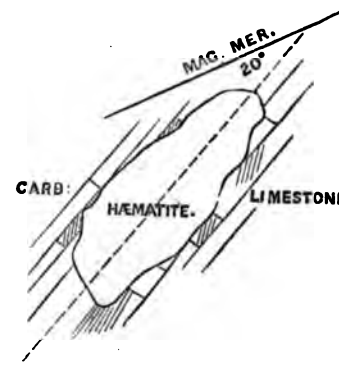

Fig. 6. (Furness Deposits.)

This remarkable fact, although nearly universal, is not quite so, being modified occasionally in one or other of two different ways; as, for instance, when a deposit is cut off by an east or west fault which has carried part of the ore away. (Fig. 7.) What remains of it may possibly be but a very small portion of the original deposit, and as all that has been removed must have had a tendency to reduce the length of the deposit in a meridianal direction, without affecting its transverse dimensions, it is possible that the part that is left may be longest in an east and west direction, that is, on the line of its original breadth. Again, a deposit may be longer in an east and west than in a north and south direction when it has more than one meridianal axis, as at Park Mines, in Furness. (Fig. 8.)

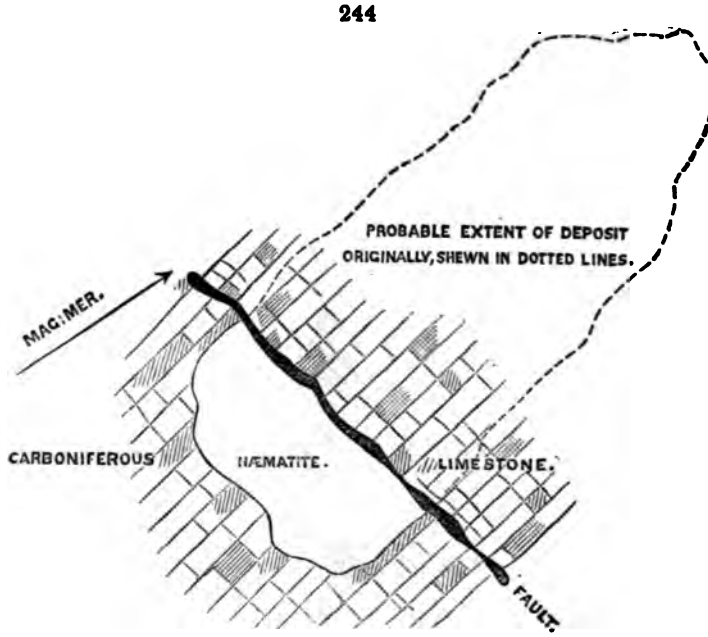

Fig. 7.

The Park deposit (fig. 8) is about 240 yards on a north and south line, and about 500 yards wide. In appearance it is like three ordinary deposits laid side by side, touching one another, and which, taken separately, are each longer in a meridianal than in an east and west direction, but the longest of them is shorter than the aggregate breadth of the three; consequently the deposit, as a whole, is longest in an east and west direction.

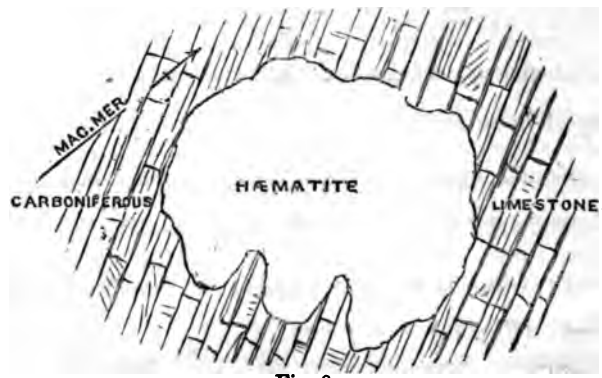

Fig. 8.

But for the two exceptions just mentioned, the hæmatite deposits will be found to be always longest in a north and south direction, and if a deposit sends out a branch or a number of branches they all follow the same law, as at *c, d, e,* fig. 9.

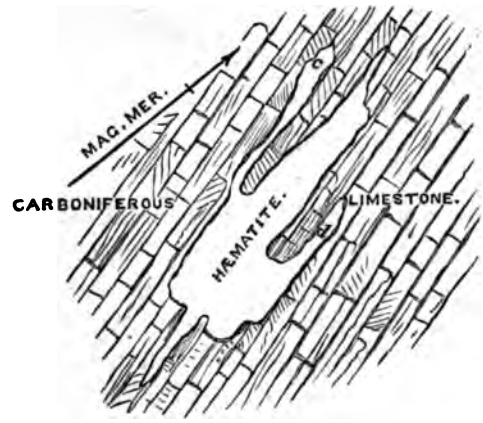

Fig. 9.

Another remarkable fact connected with these deposits is that they are almost always intersected by faults, or are lying by the side of them; and, singular as it may seem, these faults generally have the same bearing as the deposits, that is, they correspond nearly with the meridian, being about 5 degs. west of north at Whitehaven, and 20 degs. west of north in Furness. A good example of one of these meridianal faults intersecting a deposit of ore is to be seen at Salter, Whitehaven (fig. 4), where the ore on the west side of the fault is about 170 feet higher than that on the east side, and the direction of the fault corresponds exactly with that of the longer axis of the deposit of ore, both being about 5 degs. west of north. An example of a fissure deposit on the line of a fault may be seen at Plumpton in Furness (fig. 10). There are a great number of deposits of this description in Furness. They are generally known as "ginnels," when not more than 6 or 7 feet wide.

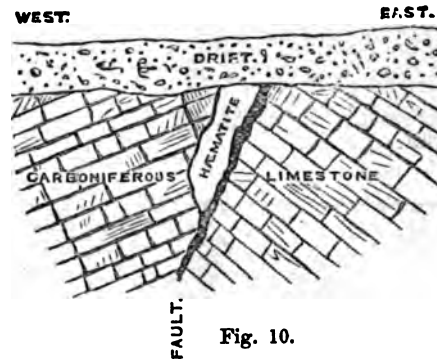

Fig. 10.

Sometimes ore is found only on one side (the downside) of these meridianal faults, as at Agnes Pit, near Whitehaven, where it occurs in the Carboniferous Limestone, on the east side of a large north and south fault. On the west of that fault the Skiddaw Slates, which cut off the ore on that side, are up to the surface, and the Carboniferous rocks off altogether (fig. 11). Other deposits similar to this occur along the same fault, both north and south of Agnes Pit.

Fig. 11.

A deposit may also be cut off by a transverse fault, as at Montreal (fig. 12), where the ore, in the Limestone, is cut off, on the north, by the coal measures, which are introduced

by a large east and west fault. That fault also cuts off several other deposits as well, among which is the deposit worked by the Crossfield Company from their No. 2 shaft, and the Crowgarth deposit.

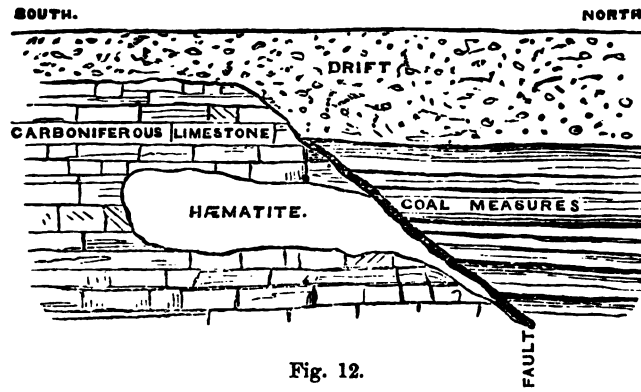

Fig. 12.

From what has now been said, I think it will be evident that there is a very great *resemblance* between the deposits of the two districts as regards their *geological position*, both containing deposits that range through almost every bed of the Carboniferous Limestone series, from the lowest to the highest. But it will also be seen that there is a very great *difference* in the *form* of these deposits, for, whilst in Furness they are mainly filled fissures or lake-like hollows, just below the drift, in the Whitehaven district, they are nearly all deep-seated cavern-like masses, beneath a thick covering of either Grits or Limestone. The cause of this difference appears to be that Furness has undergone a more severe denudation than the Whitehaven district, and that consequently the rock which possibly once overlaid the deposits in Furness has been removed. The shallower deposits at Whitehaven have no doubt suffered from a similar cause.

Internal Nature.

When we come to examine the deposits of the two districts internally, we are met by a difference quite as great as that in their form, and yet there is a resemblance no less striking than that in their positions. Speaking generally, the Whitehaven Hæmatite is much harder and more compact than that found in Furness, for whilst in the former locality it has all to be blasted, in Furness it is chiefly got by the pick, except at Lindal Moor, Stank, and Askam, where the ore is not unlike that at Whitehaven, and is mainly blasted.

1.—*Whitehaven Deposits.*—The Whitehaven hæmatite is generally of a dull red colour, and occurs in hard, compact masses, containing numerous irregular cavities, called "loughs," which range from an inch in diameter to 3 or 4 feet, and even more. These cavities are generally lined with that description of ore known as kidney ore, on which, again, there is frequently an inner lining of specular iron, quartz, and calcareous spars. The beauty of some of these loughs when first broken into is quite inconceivable to those who have never seen them. The pure, unsullied brilliancy of the crystals of specular iron and quartz with which they are adorned, produce a most brilliant effect when exposed to the light. Frequently, lying in the bottom of the loughs, there is a quantity of fine powdery hæmatite, which generally has a very greasy look and a deep stain. It has been sometimes used as a pigment.

Kidney ore does not always present itself in the interior of a large cavity, for it is sometimes found where, at first sight, there is no appearance of a lough, or of there ever having been one. On closer examination, however, it will be found that on the convex side of the kidney ore there is either a very small space, which, of course, is a lough, although of small dimensions, separating

Fig. 13.

it from the massive ore; or, it may be embedded in a mass of spar, which spar occupies what was originally a lough. Fig. 13 is a section of a lough, showing the kidney ore surrounding it, and the inner lining of spar. Fig. 14 shows the way the kidney ore occurs when the original lough hole is filled with spar.

Fig. 14.

There appears to be a general absence of bedding in the hæmatite, and some deposits show but very few joints. Others, again, contain a large number, the harder ores generally containing most. The direction of the joints is either east and west, or north and south, the majority having the former direction. In fact, the north and south joints are mostly very scarce.

Sometimes in the ore a thin irregular bed of shale is met with, and it is worthy of remark that, when such is the case, the ore for some distance is frequently very much softer both above and below it, being softest next the shale, and getting gradually harder away from it, up to 2 or 3 feet, when it assumes its regular hardness. The same thing often occurs when a deposit has either a shale roof or floor.

The softening of hæmatite in this way, when in the

presence of shale, is probably caused by the ore having a slight admixture of shale in it, the most shale being where the ore is softest, from there becoming gradually less until it vanishes altogether, and the ore assumes its usual hardness. This alteration in the hardness of the ore does not always occur when it is in contact with shale, for sometimes it is foundin a perfectly normal condition, especially when lying against black slaty shale.

The junction between the ore and the limestone in which it lies is another point worthy of notice. Sometimes it is very distinct, there being a thin parting of either shale or soft ore between them. At other times the stone and ore graduate so into one another that it is very difficult to tell where one begins and the other ends. They seem, as the miners express it, grown together, for it is impossible to separate them. If an attempt be made to break off a piece of ore from the limestone, part of the ore is almost sure to be left, or some of the limestone will come away with the ore. There is no such graduation as this, however, between the ore and the sandstone, or between the ore and shale when they are in contact, the joint between them being invariably well defined, and generally they are easily separated.

If a deposit is exposed to the drift, that is, if it is not covered by solid rock, as in the fissures and lake-basins worked by the Crossfield Company and Mr. Stirling, the ore, for several feet from the top, is generally broken up into small pieces. Some of them are slightly rounded, being mostly so near the top.

The breaking of the ore in this way appears to have been produced by the intense agencies of the drift period, which, judging from the great number of hæmatite boulders found scattered about in the drift formation, have evidently had a very severe effect upon the ore deposits of both Whitehaven and Furness.

Very few fossils have been found in the Whitehaven deposits; and the few that have are of very little value for determining the age of the deposits, as no one seems to know exactly where they came from, whether they were lying in the ore, or in the associated rocks, or, if in the ore, whether that was solid or had been broken by a fall consequent upon the working. For it is evident that in broken ground a fossil might become incorporated with the ore, although it originally laid outside altogether, in the overlying rocks. The few fossils that have been found in the deposits are mostly pieces of the stems of carboniferous plants which have been converted into sandstone.

2.—*Furness Deposits.*—The Furness ore, with the exception of that at Lindal Moor, Stank, and Askam, is, as was stated above, of a very different character to that at Whitehaven. Instead of the hard solid masses of ore we meet with in that locality, we have, in Furness, a loose incoherent mass, which has, no doubt, once been solid, but has by some means or other become either crushed into a powder or broken up into very small pieces. The powder portion having absorbed a large quantity of water, now forms a sort of paste, which fills up the interstices between the small fragments. The open works at Martin, before alluded to, afford a good example of the way in which the Furness ore occurs generally. We there see a huge mass of soft, smitty ore, in which is imbedded a large quantity of small fragments of harder ore, a few of which are slightly rounded, and here and there a large boulder of ore may be met with. There are also one or two large irregular masses of "black muck"* occurring among the ore and a quantity of clay.

* Black muck is a dark brown powdery substance when dry, consisting of varying proportions of siliceous and aluminous materials and of the oxide of iron and peroxide of manganese. As found in the mine, it is almost like a stiff paste, as it is then mixed with a large quantity of water. From the way in which it occurs, it appears to me to be the result of some chemical action on the limestone.

The clay appears to have been carried down by water percolating through the drift, and to have filled up any interstices there might be among the fragments of ore. Just under the drift the ore, for a few feet down, is very much mixed with the sand and the gravel of the drift, and sometimes a thin irregular layer of ore may be seen in the drift altogether apart from the main body of ore.

The lough-holes, that form such a common feature in the Whitehaven deposits, are here altogether absent; but occasionally a few pieces of kidney ore and spar are met with. They do not, however, occur in the beautiful way that they do at Whitehaven, lining the walls of fairy-like cavities that glitter on the approach of light like the gems in a monarch's crown, but are mixed up indiscriminately with the soft, smitty ore and its embedded harder fragments. The very fact, however, of these pieces of kidney ore and spar being there at all seems to indicate that lough-holes did once exist in the Furness ore, and that, therefore, it must originally have been solid, as the Whitehaven ore is now. Some of the harder ore of Furness is very much laminated, especially in the Askam deposit, where it sometimes encloses pieces of limestone, as shown in fig. 15, the laminations being parallel to the outside of the stone, between which and the ore there is often a thin shale parting.

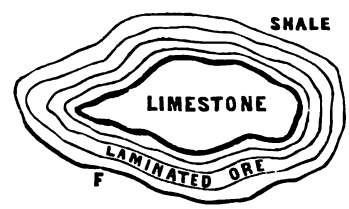

Fig. 15.

As to the way in which the broken condition of most of the

Furness ore has been brought about, Mr. Brockbank, in a paper read before the Manchester Literary and Philosophical Society, said he considered that it was the result of glacial action, that the ore was originally deposited at the Silurian edge of the limestone, and that it was subsequently transported by ice to the various fissures and hollows in which we now find it. Mr. Brockbank considers that the following section (ascertained by a borehole put down near Crossgates), taken from Bolton's "Geological Fragments," supports this theory :—

SECTION AT CROSSGATES.	Ft.	In.
Soil	2	0
Gravel and clay	24	0
Decomposed limestone	17	0
Yellow clay, mixed with iron ore	4	0
Black mould	4	0
Iron ore (dark coloured)	2	0
Black mould, mixed with iron ore	6	0
Iron ore	8	0
Decomposed limestone	7	0
Black woody deposit	12	0
Decomposed limestone	6	0
Black mould and wood	2	0
Yellow clay, mixed with ore	16	0
Black mould, mixed with iron ore	10	0
Black mould	4	0
Black mould, mixed with iron ore and limestone	3	0

After giving the above section, which he considers to be a representative section of the deposits generally, Mr. Brockbank goes on to say—"Mr. Bolton was unable to give any clue to the manner in which such remarkable sections as the above had been obtained. The occurrence of the superficial deposits, as shown in the foregoing section, is, I

believe, to be explained by the theory of glacial action, and is evidently a part of the great change wrought upon the surface by the agency of ice during the "glacial epoch," coeval with the boulder drift. The great ice-sheet which then covered all the north of England descended from the lake mountains, grinding down the surface rocks and depositing the clays and gravels in its course. The evidence of this is most strikingly displayed in the above section, each line of which apparently marks out a period and a pause in its course. The iron ore occurring in these deposits is of a dark colour, and of much lighter specific gravity than that from the veins of limestone, and it has the appearance of being all ground to powder. After exposure to atmospheric influence, it soon falls again into that state. The clays are of a bright yellow colour, and of exceedingly fine grain, being evidently the 'flour of rocks' ground down by the glacier in its passage over the Clay Slates. The unfossilised wood is in a remarkable state of preservation, occurring in large fragments, as if it had been rudely broken up and crushed, probably also by the ice. It is principally birch, and some of the trees have been found of 2 ft. diameter. In one of the pits there was also a layer of peat, giving evidence of a long period of rest and stagnation. The iron ore was thus by glacial agency transferred from its original place of occurrence from the outcrop of one reef to another, and redeposited as drift, covered up by clays and the *débris* of rocks, wherever there was a cavity to receive it."

There seems to be no doubt whatever but that some of the deposits of Furness have suffered very greatly from denudation, but I cannot for a moment think that the ore so removed was redeposited so as to form another or a number of other *workable* deposits, as Mr. Brockbank suggests, unless the original deposits were considerably

larger than any there are now. Even then it is difficult to see how the redeposited ore could be kept so free as it is from foreign substances. There is scarcely ever any other material found with it but "black mould," or, as some call it, "black muck," and that is never *mixed* with it, but lying in large masses amongst it. The comparatively small quantity of clay before mentioned as filling up some of the interstices between the hard fragments of ore has no doubt been washed down from the superincumbent drift, and, therefore, need not be taken into account in considering whether or not the ore has been redeposited by glacial action. It seems to me that if the ore had first been denuded, and then transported for some distance by an ice sheet (that had come down from the adjacent highlands) before being redeposited, there would have been many other substances found in it besides "black muck," such, for instance, as pieces of slate and porphyry, both of which rocks abound in the immediate neighbourhood, and over which the ice sheet would almost certainly travel. I am not aware, however, that there has ever been a single transported stone found in any of the deposits, *except close up to the drift*, and they are easily accounted for. The entire absence, then, of any such materials in the ore would seem to show that it has not been redeposited in the way suggested by Mr. Brockbank. Apart from such evidence as this, however, if we conclude that the Furness ore has been redeposited by glacial agency, we must, of necessity, say the same of the broken ore that is found at the top of some of the Whitehaven deposits that lie just below the drift, for, to all appearance, it is exactly like the generality of the Furness ore. But it is evident that, at Whitehaven, that condition has resulted from the breaking-up of the originally solid ore, *in situ*, and it seems to me that the fragmentary character of the Furness ore may have been

brought about in the same way, only the cause, whatever it has been, whether ice or water, has had a longer duration in Furness, and, consequently, has affected the ore to a much greater depth than at Whitehaven.

As regards the above section, I do not consider that it at all represents the mode in which the majority of the ore deposits occur, as Mr. Brockbank says it does, but, on the other hand, that it is a comparatively exceptional section, for, although there are, no doubt, one or two places in the district where such sections may be obtained, yet I venture to say, with all due respect to Mr. Brockbank, that there will be found twenty sections like the following for one of the above:—

General Section of Furness Deposits.

Drift, consisting of alternations of clay, sand, and gravel.
Iron ore.
Limestone.

In order to get a clear idea of the way in which such sections as that referred to by Mr. Brockbank, are produced, it is necessary to know that the Carboniferous Limestone of Furness contains a large number of caverns. They traverse the district in almost all directions, and act as a sort of underground water-courses. They are, consequently, a great source of annoyance and expense to mine proprietors, who not unfrequently have to drain a very large tract of country in order to keep their mine in a workable state. In fact, to such an extent do these caverns act as water-courses that there is almost an entire absence of surface streams, the water simply percolating through the drift and then being carried off by these underground channels. About three-quarters of a mile from Dalton there is a small plot of water known as Standing Tarn. It is situate in a basin, out of

which there is no surface outlet, and yet the water in the severest floods never rises beyond a certain point in it, showing that there must be some underground passage which carries it away. The passage is probably one of the caverns I am speaking of. This tarn, remarkable as it is in its physical features, is but the type of several others that are to be found on the mountain limestone of Furness. There is one at Longlands, into which it is said chaff has been thrown that was afterwards pumped from the Stainton Mines, which are about half a mile away from the tarn, thus proving the existence of an underground communication of some sort between the two places. As, however, there is a fault running nearly in a direct line between the tarn and the mine, the water may possibly find a passage along that. A number of other examples might be adduced to show the existence of these caverns, but I will only mention one more. In boring in limestone it occasionally happens that the rods suddenly fall a foot, or eighteen inches, or even as much as two feet at once, and the water then leaves them, and makes its way out of the side of the hole. To explain this we have only to suppose the existence of a cavern, which intercepts the path of the rods. This cavern, upon being broken into, will, of course, carry away all the water; and, moreover, the rods, being unsupported, will fall until they strike the bottom of it. The loosing of the water from a borehole in this way has frequently been looked upon, by those who hunt after "signs," as an indication of the proximity of iron ore, but the absurdity of such a thing must be quite evident to anyone who will give it a moment's consideration.

When any of the numerous caverns, just referred to, approach so near the surface that the roof is unable to support the super-incumbent drift, a depression in the ground ensues. These depressions are known as "sinks" or swallow

holes," of which there are some dozens in Furness. Some of them, when occurring near stream beds, have been known to engulf the whole of the water conveyed by streams of no small capacity. These streams, especially in flood times, would, in all probability, carry down with them, and deposit in some part or other of the cavern, a considerable quantity of clay and stones, and even timber. It is also possible that a small quantity of iron might find its way down too, and become mixed with the clay and stones. Conditions such as these, it is submitted, render easy of explanation such sections as that given by Mr. Brockbank, without calling in the aid of glacial action at all, and make it less probable than ever that the ore deposits of Furness—or any one of them that is worth working—have been placed in their present position by ice action. We have only to suppose that the positions now occupied in that section by the deposits of clay and wood, &c., were originally caverns, and that they communicated with the surface in the way mentioned above, and all the peculiarities of the section are explained. As to the black muck, I am of opinion, from the way in which it generally occurs in the deposits, that it was produced *in situ*, and has resulted from some chemical action on the limestone.

No fossils have been found in the soft, broken ore of Furness, but the harder ore at Lindal Moor has yielded a very large number, all of which belong to the Mountain Limestone. They are sometimes converted into pure hæmatite, and at others are a mixture of limestone and ore, as if in a state of transition.

From what has now been said respecting the ores from the two districts, it will be evident that there is a great *difference* in their mechanical condition. The difference, however, is only *mechanical*, for *chemically* they are *nearly alike*, that is, if we take only the harder fragments of the Furness ore, but in the mass the Furness ore is inferior to

that at Whitehaven, as it contains more siliceous and aluminous materials, owing to the presence of the infiltrated clay, which it is impossible to separate in working. These remarks respecting the infiltrated clay do not apply to the compact ore of Furness, as found at Lindal Moor, Stank, and Askam, and which is nearly, if not quite, equal to the Whitehaven ore, but only to the soft, broken ore found in that district. The following analyses will give some idea of the difference there is between the two ores :—

ANALYSES OF FURNESS ORE.

	Gill Brow. (Broken.)	Lindal Moor. (Compact.)
Peroxide of iron	86·50	94·23
Protoxide of manganese	0·21	0·23
Lime	2·77	0·05
Magnesia	1·46	trace
Carbonic acid	2·96	—
Phosphoric acid	trace	—
Sulphuric acid	0·11	0·09
Silica	6·18	4·90
Alumina	0·30	0·12
	100·49	99·62
Metallic iron	60·55	65·98

ANALYSES OF WHITEHAVEN ORE.

	Cleator Moor. (Compact.)	Parkside. (Compact.)
Peroxide of iron	95·16	98·26
Protoxide of manganese	0·24	—
Silica	5·66	1·59
Alumina	0·06	—
Lime	0·07	trace
Magnesia	—	trace
Sulphur	trace	—
Phosphoric acid	trace	—
Phosphate of iron	—	0·30
	101·19	100·15
Metallic iron	66·61	68·78

I have now, I believe, pointed out the main distinctive features of the ores found in the two districts. Taken in conjunction with the conclusions previously arrived at, regarding the form and position of the deposits, we have, speaking generally, in the Whitehaven district, a series of deep-seated cavern-like deposits of hard, solid ore; and in Furness, fissures and lake-like hollows, containing a heterogeneous mass of soft and hard hæmatite, mixed with clay and black muck.

Their Origin.

To account for the origin of these splendid deposits of hæmatite, although, perhaps, of the last importance in a commercial point of view to the districts in which they are found, would be a matter of no little interest to science; and yet, for some reason or other, the subject has hitherto been almost entirely neglected, and, when attempted, it was on such very incomplete data, that the results arrived at were not so satisfactory as they otherwise might have been. I believe, however, that the description of these deposits, given in the first and second parts of this paper, includes almost every fact of any importance that is yet known respecting them, and, therefore, affords a moderately safe foundation to build a theory upon.

Igneous Origin.—It is often held that these deposits owe their origin to some deep-seated igneous action—that the ore was originally ejected from below in the condition of a hot-boiling liquid, which settled and consolidated in previously existing caverns, fissures, and hollows. At other times, it is urged that the ore was placed in its present position in such a manner as to render the previous existence of caverns and fissures quite unnecessary. What the precise manner was in which it was so laid is not stated, nor even

hinted at. I think, however, that it will be found infinitely more difficult to reconcile any igneous origin with the facts, if the existence of caverns and fissures into which the ore could run, is not assumed; for, how otherwise are we to account for the undisturbed state of the adjacent rocks. There is not the least sign whatever of any force having been employed by the ore to displace the limestone, but if there were no caverns into which it could run and settle, it is evident that the limestone must have been displaced by the ore, for no two bodies can occupy the same space at the same time. The absence, then, of any such disturbance as would necessarily arise by the forcible displacement of one body by another would seem to show that the ore, if of igneous origin, must have been deposited in caverns. Besides, why should the ore have such a preference for the limestone and so carefully avoid beds of sandstone, and shale, as we have seen that it does, if it was not laid in caverns? Why do we not find it lying in other rocks as well as limestone? If it had been ejected from below we should have expected it to pass through all rocks alike, as other igneous deposits do, and not to have shown a most decided preference for one particular kind of rock. This difficulty, however, is at once surmounted if we suppose the ore to have been laid in caverns or fissures, for it is well known that both caverns and fissures greatly abound in limestone, and that it is chiefly in that rock they are found. Therefore, if the ore was laid in caverns and fissures, we should expect to find it mostly occurring in limestone, and such actually is the case.

It would seem from the above, that the previous existence of caverns and fissures is a most essential part of an igneous theory, for in no other way can we account for the undisturbed state of the surrounding rocks.

Let us see, then, how far an igneous theory, including this feature, explains the following sections, figs. 16 and 17.

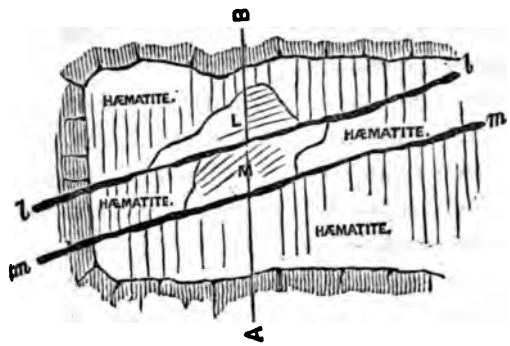

Fig. 16.

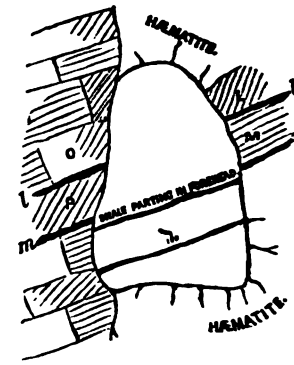

Fig. 17.

The sections from which these sketches were taken, are at present to be seen in one of the Salter and Eskett Co.'s pits, at Whitehaven. Fig. 16 is a longitudinal section along a north and south heading, and fig. 17 a cross section of same at A B. It will be seen from fig. 17 that the heading in which the sections are exposed is driven just on the edge of the ore, and that, on the west side, there is nothing but limestone. On the east, it is nearly all ore, with the exception of a piece of limestone near the top, L M. This piece of limestone was originally joined to that on the west side of the heading at O P, fig. 17, but the connection was severed by the heading. Even now, however, the identity of the beds can be traced, for the shale partings shown at *l* and *m* may be traced round by the forehead from one side of the heading to the other. These partings, it will be noticed, maintain an uninterrupted course in both the limestone and ore, having the same dip, and being exactly the same distance apart when in the ore as when in the limestone. They have also the same lithological character as those partings in the limestone, and form, with them, in every respect, relations which leave no doubt whatever but that they were both formed at one and the same time. Such being the case, it is evident that the ore which they intersect cannot have been thrown down in

a cavern previously formed in the limestone, for, if so, these thin partings, being now in the same relative position to the surrounding rocks as they were when first deposited, must have stretched across that cavern, and must have been able, not only to stand without any intermediate support across that opening, which would be several fathoms wide, but also have been able to resist, undisturbed, the flowing force of a large mass of molten metal, rushing, probably, with great and furious force into its cavernous receptacle. Such things are, however, altogether impossible, for it must be evident to anyone that these thin partings could not possibly stand for a moment if the support was taken from them, as it must have been if they spanned across a cavern; consequently, I think we may safely say that the ore in question was not deposited in a cavern. But if it was not deposited in a cavern, and a cavern is, as we have shown, an essential part of any igneous theory, it follows that the ore in question *cannot be of igneous origin.*

Perhaps it may be thought possible that the ore may have been formed at the same time as the limestone in which it is lying, then there would be no need of asuming the existence of a cavern. Let us see how far this is possible. Now, limestone being the result of organic agency, would necessarily be of comparatively slow growth, increasing only by inconceivably small increments, but the ore, if of igneous origin, would, in all probability, like those rocks generally, be produced by a single instantaneons effort, and, consequently, being of more rapid growth, would overflow the limestone and form a sort of bed. .There is, however, no evidence of any such overflow, or bed-like formation, either in the particular ore in question, or in the deposits generally. On the contrary, many of the deposits are more like veins than beds. Even such deposits as Parkside and Bigrigg, in which there is a slight resemblance to a bed, send out from

the main body, at various points, a number of vein-like branches, shewiug that the ore could not possibly heve been formed at the same time as the limestone, and, therefore, that it cannot be *of igneous origin.*

Again, if the ore had an igneous origin, we should expect to find, in the surrounding rocks, some evidence of the calcining effects such huge masses of matter must have possessed when elevated to a temperature sufficient to produce liquefaction. The limestone and sandstone, one would think, should have been altered in texture, and the shale hardened, but there is no such evidence whatever, for the rocks in contact with the ore are, to all appearance, in exactly the same condition, lithologically, as the same classes of rock are when away from the deposits altogether. Besides, on the assumption that the ore had an igneous origin, how are we to account for its laminated condition in many places, for the numerous carboniferous limestone fossils that have been found in it, and for the interstratified beds of shale, many of which are, like those in figs, 16 and 17, but continuations of shale beds, intercalated with the surrounding limestone.

But it may be said that the ore saw possibly deposited by sublimation. It is evident, however, that it could not have been so deposited in the case of figs. 16 and 17. Sublimation assumes the existence of fissures or cavities, in which the sublimed vapours may accumulate and condense. But we have just shown that the ore in figs. 16 and 17 cannot possibly have been deposited in a cavern. Therefore it ncanot have originated by sublimation.

There are numerous other arguments, equally powerful, which might be adduced to show the impossibility of an igneous origin, but it is hoped that what has already been said will be found sufficiently conclusive on that point to render it quite unnecessary to say more.

The arguments generally adduced in favour of an igneous origin of hæmatite are based upon the kidney-like structure of some of the ore, and the existence of the lough-holes, both of which features the advocates of this origin believe could only have been produced by the action of fire. On these two facts they found a theory which is opposed to almost everything else that has yet been proved without first showing that the facts on which they rely so much are incapable of production in any other way. That the radiated, kidney-like, and concretionary structure of hæmatite can be produced without fire is certain, for I have seen it in the incrustation of a locomotive boiler using water holding a large quantity of iron and lime in solution. It may also be seen in the stalagmite coating of caverns, and in many other aqueous deposits. Professor Bischoff, in his "Chemical Geology," mentions having seen a quantity of iron resembling brown hæmatite, and possessing these kidney-like forms, that had been deposited in cavities, to which the air had access, from springs having a temperature of about 91 degrees. The lining of cavities in this way suggests to us a probable mode of the origin of loughs in the wet way, for if the incrustation continue to increase for an indefinite time, the cavity will, in the end, become so small as to deserve no other name than a lough. Seeing, therefore, that the bulk of the evidence is altogether opposed to an igneous origin, and that the only two facts which seem to favour it can be explained in another way, I think we may safely conclude that the hæmatite of Whitehaven and Furness *had not an igneous origin.* Let us, then, try to account for it in some other way—by the only alternative—the supposition of an aqueous origin.

Aqueous Origin.—Numerous attempts have been made from time to time to explain these deposits in the wet way, but none of them are quite satisfactory. The segregation

theory, so often employed to account for the formation of regular veins, has more than once been adopted in the case of these deposits, but not with perfectly convincing effect. How, by that theory, can we explain the existence of fossils in the ore, or the intercalated beds of shale, such as are shown in figs. 16 and 17? In order that a deposit may be formed by the segregation process, it is necessary that there should be a cavity into which the ore may be deposited; but it is quite evident that if a cavity had ever been where the ore now is, shown in figs. 16 and 17, that the shale beds, which intersect it, could not have possibly retained their original relative position, as they have done. The same argument is equally fatal to most of the other theories that have been put forward, since they all assume the previous existence of caverns, and consider that the whole of the iron was thrown down in those caverns. But it has been shown, however, that some of the ore, at least, was *not laid in caverns;* consequently, that ore cannot have originated either by the segregation theory, or any other which supposes that it was laid in a cavern.

Having thus briefly shown the inadequacy of former theories to explain all the facts presented in these deposits, I will proceed to sketch out one which to me seems to do so as nearly as may be.

My impression is that the hæmatite was originally deposited as a carbonate, in which form it was thrown down, *partly by replacing the limestone, and partly in previously existing caverns.* The *modus operandi* probably being as follows:—Bicarbonate of iron, in solution, entering the numerous cavernous spaces and joints in the limestone, would, by its contact with the carbonate of lime forming that rock, become decomposed, the carbonic acid in the bicarbonate of iron acting on the limestone. The result of the reaction would be bicarbonate of lime and carbonate of

iron, the latter of which, being insoluble in water, would be thrown down, and bicarbonate of lime, being soluble, would be carried off in solution. Carbonate of iron would also be produced, by the abstraction of some of the carbonic acid from the bicarbonate, through evaporation into the caverns. The precipitated carbonate, however, thrown down, would, in course of time, by exposure to the air and water that might pass through the joints and cavernous spaces in the limestone, become converted into sesquioxide, the state in which we now find it. Both the above operations, to produce the carbonate, might frequently be going on at once in the same deposit; for instance, if water, holding the bicarbonate of iron in solution, found its way into a cavern, part of the iron contained in that water might be precipitated by some of the carbonic acid in the bicarbonate being evaporated, and part, by the remainder of that carbonic acid uniting with the carbonate of lime forming the sides of the cavern, and leaving the iron in the state of a carbonate, which, being insoluble in water, would be thrown down in the cavern. The former process may frequently be seen going on now about any coal-field, where bicarbonate of iron, in solution, issuing out of the earth and becoming exposed to the atmosphere, loses part of its carbonic acid by evaporation, and the iron is then thrown down as a carbonate. This, eventually, by further exposure to the air, becomes converted into sesquioxide, and forms the ochreous sediment, called "canker," so common in water coming from coal-fields. The latter of the two operations mentioned above would, in all probability, extend for a considerable distance from the walls of the cavern into the limestone, the carbonated water finding its way in by the joints. This would, of course, make the deposit very much larger than the original cavern, and so enable us to get over the objection sometimes raised, that many of the deposits

that have been found are much too large to have been formed in caverns.

That some of the iron, at least, has replaced the limestone in this way, is proved by the fact of numerous carboniferous limestone fossils having been found in the ore, some of which are only partially converted into hæmatite. Still stronger evidence, however, is furnished by the section shown at figs. 16 and 17. When trying to reconcile those sections with an igneous origin, it was shown that the iron could not possibly have been deposited in a cavern, on account of the inability of the thin shale partings to stand without support. The same arguments were also shown to apply if the iron had an aqueous origin, and was supposed to have been all deposited in caverns; for, although there would not be the same disturbing force when the iron was quietly deposited from an aqueous solution as there would when it was rolling in as a hot molten mass, and consequently, the shale partings that must have stretched across the cavern would not be so likely to get disturbed, still we have the difficulty of ever getting them to stand at all, apart from any disturbing influence; for it is evident that they are not, and never could have been, sufficiently strong to bear their own weight across a cavern several fathoms wide. Therefore, if there ever had been a cavern there, these partings must have fallen away. Their existence, however, now, in the same relative position to the surrounding limestone that they occupied when first deposited, shows that there cannot have been a cavern there; so that the ore could not have been deposited in one. The same sort of reasoning shows that all those deposits which have a shale roof could not have been laid in caverns, for if they had, the shale roof would have fallen away, as it does now when the ore is taken from below it in working. If even only a very small area of it be exposed to atmos-

pheric influence now for only a few weeks or days, it falls away; so that it is scarcely likely that it would stand, perhaps for years, when unsupported for an area of several thousand yards, as it must have done if the space now occupied by some of the ore deposits with shale roofs had been caverns. It is also equally certain that the ore could not have been deposited at the same time as the limestone; for if the iron had been in solution at the time the limestone was forming, they would have become mixed together, and would not have appeared to us under the two distinct characters of nearly pure hæmatite and nearly pure limestone, as they do, but simply as a mass of irony limestone, or limey iron. We shall get over all these difficulties, however, if we suppose that the space now occupied by the ore was originally a mass of limestone, laid down at the same time as the limestone now surrounding the ore, and that it has subsequently been replaced by the ore in the way before suggested; that is, by chemical action. Under this supposition we escape the difficulty of the thin shale partings having to stand across a large opening without any intermediate support, for the support would then never be taken from them, because, as the limestone was removed, the iron would be thrown down in its place. We also see, by supposing part of the ore to have originated by the replacement action just suggested, how it is that the ore and limestone, in some places, pass so gradually into one another as they do, appearing often as if they were grown together. It is evident that the transition from limestone to hæmatite must be a slow and gradual process, and that, therefore, we ought to find between the pure limestone and the pure hæmatite a regular gradation from one to the other. As has been before mentioned, such actually is the case; and it is difficult to see how it could possibly have been brought about in any other way than through the

replacement of the limestone by the hæmatite. The same action will also account for the appearance in the ore of those fossils which seem to be only partially converted into hæmatite, as well as for those which have been completely changed. It is well known that limestone fossils generally withstand the action of carbonic acid much longer than the rock in which they are imbedded, and some fossils resist it longer than others; so that, if we suppose the ore partly to have replaced the limestone in the way suggested, it is evident that the carbonic acid, by which the re-actions were brought about, would have less effect on the fossils contained in the limestone than on the limestone itself, and less on some fossils than on others. Consequently it would take longer to convert a fossil into hæmatite than it would the ordinary limestone; and some fossils would take longer than others. Hence the different aspects they appear under; whilst one fossil is a mixture of limestone and hæmatite, and has a dull red earthy fracture, another will be found of pure hard, shining purply hæmatite. The occurrence of these fossils in this way, I submit, could not have been produced in any other way than by the chemical replacement process. It has been shown above that the ore could not have been formed at the same time as the limestone. But, if it was not, how are we to account for the appearance in it of organisms, entirely converted into hæmatite, belonging to the carboniferous limestone, unless we call in the replacement process. As regards the sandstone fossils said to have been found in the ore at Whitehaven, so much uncertainty attaches to them, with respect to the exact position they were found in, that it is difficult to say anything about them. I think it is very likely that they were not found in the ore at all, but came out of the sandstone belonging to the millstone grit formation, which forms the roof of so many of the deposits; or, probably,

they were lying between the ore and the sandstone, and fell away with the ore when it was worked.

In the same deposit in which the sections given in Figs. 16 and 17 are exhibited, and not far from those sections, there is another and different one, showing that some of the ore has been thrown down in caverns. Fig. 18 is the section referred to.

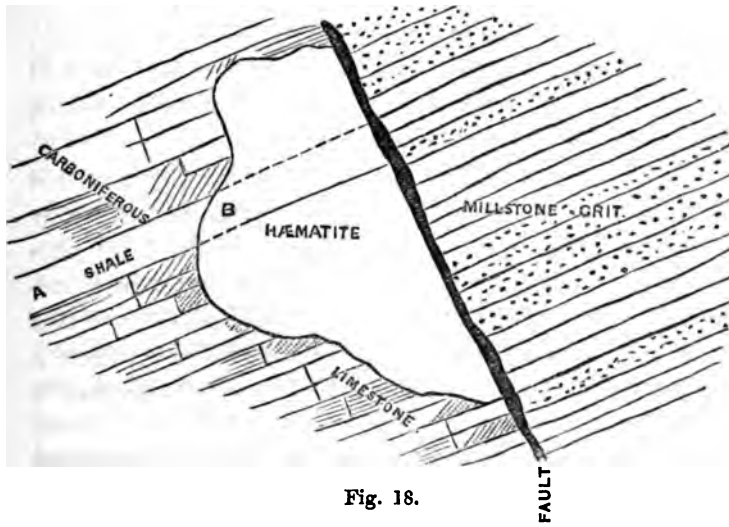

Fig. 18.

It will be seen that the bed of shale, A, is abruptly cut off on the right by the mass of hæmatite, B. But before the ore was deposited, this shale bed no doubt extended right across where the ore is now, and on into the limestone on the other side. Perhaps it is not possible to verify this now, as the deposit has been intersected by a large fault, and consequently the relative positions of the rocks are altogether different to what they were originally. But it is evident that if the shale bed, A, did not extend across where the hæmatite now is, the ore must have been formed at the same time as the rocks by which it is surrounded. It has, however, been shown that the ore is younger than the rocks in

showing that the carbonated waters have, at one time, acted on those planes, so that if it be true that the hæmatite was partly deposited in caverns and partly by replacing the limestone (and we have shown that it must have been so) why should it all have been laid in those caverns having a bearing north and south, and why is it that the replacement process has never manifested itself in an east and west direction? These questions are difficult to answer, but, probably, the preference of the deposits for a north and south direction is owing to the fact that the divisional planes, having that bearing, are much more persistent, both horizontally and vertically, than those in an east and west direction, and, consequently, they would be more acted on by the carbonated water. Or, the hæmatite may have been deposited before the transverse planes existed, that is, while the rock was only intersected by the meridianal planes. This, however, is only conjectural, as, I believe, it has not yet been ascertained which set of planes were formed first, or whether they were not formed together.

The divisional planes of the carboniferous limestone may be compared to the two sets of vertical joints in a brick-laid pavement of considerable thickness, in which the bricks are so laid that one set of joints are perfectly continuous, both horizontally and vertically, whilst the other set, at right angles to the former, break joint. The former set would correspond to the meridianal planes, and the latter to the transverse planes. Yet not quite, either, for in that case we should expect to find all transverse planes of no greater length than from one meridianal plane to another. A more correct notion of them will be obtained if we imagine a similar pavement built with bricks of different lengths, instead of being all of the same length, as is usual; the one set of joints would then be continuous, as before, but the other would be greatly altered. They would not then regularly

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break as when the bricks were of the same length, but it might, and no doubt would, so happen that several of them would form a continuous line. This is just the way with the divisional planes; whilst those with a meridianal direction are always continuous and of great length; the transverse planes generally extend only from one meridianal plane to another, but may do so occasionally over many of them. This being so, it is but natural to expect that the carbonated waters would have a greater effect on the meridianal planes than on the transverse planes, for they would expose a much larger surface to the action of the water. By way of illustrating this, it may, perhaps, not be uninteresting if I here describe in detail one of the numerous caverns which abound in these districts. Perhaps the one best suited for that purpose is that near Stainton, in Furness, discovered by the working of a quarry which supplies the Barrow Hæmatite Iron and Steel Company with a flux. The entrance to this cavern is about midway up the breast of the quarry, and about 50 feet below the original surface (figs. 20 and 21). For a short distance from the entrance, the cavern goes in an easterly direction. It then makes a sudden turn and pursues a southerly course for a few yards. Turning again to the east, it continues in that direction for a short distance, and then makes another turn to the south, and so it goes on taking alternately an easterly and southerly course until we are about 200 yards in from the entrance. During the whole of that 200 yards, the cavern is never wider than 8 feet nor less than 3 feet, the average breadth being about 4 feet. Its greatest height is about 7 feet, and in one place it dwindles down to 18 inches. This, however, is only for about a yard, and occurs just in from the entrance. The average height is about 4 feet 6 inches. In some places it has all the appearance of a drift-way that had been driven by man, except for its water-worn sides, for, in one or two places, it

is straight for nearly 30 yards, and of a uniform width of 4 feet, and about 5 feet high. The dip of the rock in which it is formed is to the south-east, and as it is mainly hollowed out of one bed of stone for the first 200 yards, those parts of it in that length which have a southerly direction have the same inclination as the rock, whilst those running east and west are nearly level, being on the strike. Every time, therefore, the cavern changes its course, it also changes its inclination. First it goes level, that is, on the strike of the beds, then down an incline, or on the dip, then level again, and so on to the end. Here and there, at various distances apart, and on both sides of this main passage are numerous small branches running out from it; most of them are, however, too small to admit any person. There are also several small shaft-like passages running upwards from the roof (fig. 21), which, in all probability, communicate with the overlying drift, as the cavern for the first 200 yards is nowhere more than about 25 feet below that formation. The walls of the cavern are, in many places, covered with a thick coating of carbonate of lime, and sometimes, but not often, this is found on the roof and floor, in the form of stalactites and stalagmites. Where the walls are not covered with this coating they are often thickly set with fossils which stand out from the stone in high relief, illustrating what has just been said respecting the greater endurance of fossils, when under the action of carbonic acid. Scattered along the floor of this drift-like passage in several parts there is a large number of boulders and a quantity of shingle, formed out of rocks that are found in the neighbourhood, such as Porphyry, Coniston flag, and Coniston grit. Probably, they have fallen from the overlying drift down the shaft-like passages that ascend from the roof. At about 200 yards from the entrance we come to the end of this long, low, narrow passage, and then find a great

change. The cavern there turns to the north, and suddenly opens out to about 20 feet wide and 30 feet in height. The floor dips at an angle of 46 degrees, whilst the roof is nearly level, so that the further we proceed along the cavern the higher it gets. The length of this chamber is about 45 feet. In the floor at the north end of it there is a small drop-hole, passing down which, for about 20 feet, by means of a rope, the end of which has to be fastened away back in the cavern, we come into another large chamber. This is about 60 feet long and 30 feet broad, with a height of about 17 feet, and has a parallel direction to that above. Leading out of the north end of the second chamber in an easterly direction, there is a passage about 8 feet wide and 45 feet long, from which, again, there are two others branching out to the north, but into which it is impossible to get far now, as they are choked up with large pieces of limestone and hæmatite, and a quantity of Silurian shingle, which have, probably, fallen down some passage from the drift. In the floor of the passage out of the second chamber, and between the ends of the two branches, there is another drop-hole similar to that by which we descended into the second large chamber. Down this, I believe, no one has ever been, but it appears to lead to another chamber which is nearly full of water. On throwing a large stone into the water there comes up therefrom a hollow bubbling sound, which lasts for several seconds, showing that the water must be very deep. On the floor of the two large chambers, and the passage leading to the last drop-hole, a quantity of large angular pieces of limestone, which have fallen from the roof, lie scattered about, and also a quantity of shingle. These are mostly covered with a thick coating of clay, as is also the otherwise uncovered portion of the floor.

The two general directions I mentioned as being

alternately taken by the different portions of the cavern, correspond exactly with those of the divisional planes of the limestone in which the cavern is formed. (See fig. 20.) This coincidence of direction may be seen in the roof of the cavern all the way along, where we find, alternately, the transverse and meridianal planes, according as the cavern has an easterly or southerly direction. Upon an examination of figs. 20 and 21, it will be seen that those parts of the cavern which have an east and west direction, or are on the transverse planes, are only of comparatively small dimensions as regards their height and breadth, although of considerable length, the largest part of the cavern having a north and south direction. This I have invariably found to be the case in other caverns as well as this; indeed, it follows, from the nature of the divisional planes, that it should be so, and makes it extremely probable that the preference of all the worked hæmatite deposits for a north and south direction has simply arisen from the greater persistence of the divisional planes with that bearing. If so, it is not at all impossible that there may be some deposits having an east and west direction. Like the caverns, however, with that direction they will be much smaller than those bearing north and south. Probably, there may be some of them amongst those deposits that have been proved by boring, but never worked, on account of being too small. Or, they may be confined to branches from the main north and south deposits.

Having now attempted to explain the various phenomena of the mine, and the probable way in which the deposits originated, there remains for me only to consider briefly the source of the iron which now forms these deposits. This, it appears to me, was probably the Coal Measures. It is well known that the sandstone and shales of the Coal Measures

contain a large percentage of iron; and as those rocks at one time probably overlaid the whole of the area now occupied by the limestone, containing the hæmatite, it is not difficult to conceive how much of the iron they contained might be dissolved by the carbonated water permeating the rocks, and find its way below, especially if any faults existed; for the retentive nature of the clays and shales in the Coal Measures would prevent much water from finding its way through the mass of rocks; consequently it would have to descend by the faults. The carbonated solution of iron, thus carried down, would attack the underlying limestone, when it had descended so far, along the lines of those faults, and consequently the iron would be deposited on those lines—a state of things we find actually to exist in a great number of deposits, as already mentioned. Whether, however, the faults which we now find intersecting the deposits were, or were not, in existence at the time the hæmatite was deposited, is difficult to say; for although most of them contain a large quantity of *débris*, where they intersect the ore, as if they had been formed subsequently to that ore, yet, if the ore adjoining the fault had been deposited by the chemical replacement process, it is quite possible that such a state of things might occur, although the ore had been deposited long after the fault occurred. If, as just suggested, the iron was derived from the Coal Measures, and found its way down by the faults into the limestone, it is not at all improbable but there may be a great number of deposits that we now know not of, lying under the Whitehaven coal-field, and under the Yoredale shales of Furness. The deposit at Stank, in the latter district, partly favours this idea, although that deposit is not a very great way in from the rise edge of the Yoredale rocks. It would, however, be very much further under once than it is now, before the district had suffered so much

from denudation. The same may be said of those deposits, in the Whitehaven district, that lie below the grits.

Their Age.

This is a question which has engaged the attention of some of our ablest geologists, but it is as yet far from being settled. Mr. Binney argues that the hæmatite is of lower carboniferous age, from the fact of his having found therein a fossil *(Sigillaria vascularis)* peculiar to that horizon. In a paper read before this Society, Mr. Binney says, "the occurrence of such fossil plants as sigillaria, lepidodendron, and calamites, occurring as they do in beds from the lowest to the highest carboniferous strata, would give little evidence of any particular part of that epoch; but the *Sigillaria vascularis*, so far as is yet known, is confined to the lower coal-fields, not far in geological position from the Ipstones hæmatite, Staffordshire, and the valuable clayband ironstones, now wrought at Hazlehead, west of Penistone. The deposits of hæmatite in Furness and Cumberland, found in hollows of the carboniferous limestone, and covered up by till, or 'pinnel,' as it is locally termed, or more rarely by Permian breccia, are so much alike in all their characters, that if the origin and age of one of them are clearly proved, those of the rest must follow almost as a necessary consequence." Mr. Binney considers the plants must have floated in with water which held the oxide of iron in solution, or else they must have fallen into the cavities, when such were open at the top, and the ore was in a soft state.

Professor Harkness and Sir Roderick Murchison agree that the formation of the deposits took place about the dawn of the Permians, arriving at that conclusion from the fact that several deposits in Furness are overlaid by a breccia locally called "crab rock," which they consider to be of early Permian age. In a paper on the Permian rocks of

the north-west of England, published in the Quarterly Journal of the Geological Society, vol. xx., part 2, they say: —"The mode in which that valuable ore of iron, hæmatite, is found in pre-existing cavities of the carboniferous formation, and sealed up by crab rock (Permian breccia), is a matter of great geological interest. Joints, fissures, and caverns were doubtless formed in the older rocks, antecedent to the deposition of the Permian strata; and in these the ores of iron so widely diffused throughout the Permian rock have, in this position of the north-western region, assumed the characters of hæmatite. This circumstance justifies the inference that these hæmatite ores are the result of an agency which ushered in the Permian epoch. The earlier rock of both England and Scotland are strongly impregnated with iron, their composition consisting principally of silica and an oxide of this metal. This latter substance originated from the same source which, during the commencement of the deposition of the Penrith sandstones, filled up the fissures in the carboniferous limestone. This conclusion is applicable not only to the Ulverstone district, but also to that of Cleator, south-east of Whitehaven, where valuable deposits of hæmatite are also obtained from the cavities and fissures in the carboniferous limestone, which at one time was here covered over by an extension of those Permian *Breccias* and sandstones now forming an escarpment a short distance west of Cleator Moor."

With some diffidence I am inclined to differ from these eminent authorities as to the age of the "crab rock." Having carefully surveyed the whole district, I believe that this crab rock belongs to the drift period, and not to the Permian system at all. The reasons for such a conclusion are as follows:—

1st. It is intimately connected with the drift at every point of its appearance.

2nd. There is an entire absence of bedding and jointing in it, unlike most old *Breccias*.

3rd. It is nowhere overlaid by the upper Permian rocks. At the point where the upper Permians are seen resting upon the carboniferous rocks, and where we should expect to find it, if it really was of lower Permian age, it is not to be seen.

The *Breccia* appears to me to have been produced by the same force as caused the breaking up of the Furness hæmatite, and at the same time, that is, during the drift period. If, then, that is the age of this crab rock, it affords no evidence whatever of the Permian age of the hæmatite, for that ore might (for anything this *Breccia* proves to the contrary) have been deposited during the Trias or even during the Jurassic or Tertiary periods.

The theory proposed by Mr. Binney also seems to me to be open to very great objection. If the plants he speaks of had been floated in along with the water which held the iron in solution, as he supposes, how is it that the same water did not carry in with it some of the sand and mud that was then thrown down in such quantities. An opening sufficiently large to admit a moderate sized carboniferous plant, one would expect, would be almost sure to pass an enormous quantity of sedimentary matter as well. There is, however, no evidence in the deposits of any such matter having been carried down into them, and, therefore, I think it is not at all likely that the plants which have been found in the deposits, converted into hæmatite, were floated in with the solution of iron, as Mr. Binney suggests.

Probably, the nearest that we can yet come to the age of the hæmatite is, that it was deposited after the carboniferous limestone, but before a great part of the Permians. It has been already shown that it is younger than the carboniferous limestone, for some of it was deposited in caverns in that rock. That it was deposited before a great part of the Per-

mians, is proved by the fact that several hæmatite pebbles have been found in the *Breccia* representing the lower Permians at Whitehaven. That *Breccia* is supposed to be the terminating member of the lower Permian, and equivalent to the "rotten bockrams of Appleby." If so, it is possible that the hæmatite may be either of the age ascribed to it by Professor Harkness and Sir Roderick Murchison, or it may be still older, as suggested by Mr. Binney. I submit, however, that neither of the times named by these authorities has been satisfactorily proved. Perhaps, as more facts are revealed in working the deposits, we may be able to arrive at their age more nearly than we can at present. In the meantime, I do not think there is any positive evidence whatever to warrant us in saying more than that *the hæmatite is younger than the carboniferous limestone, and older than a great part of the Permians.* Circumstantial evidence would, perhaps, lead us to the conclusion that its formation was collateral with the Coal Measures. The large amount of carbonic acid that would then be dissolved in the waters, owing to the decomposition of the immense mass of vegetable matter required for the production of the coal seams in those rocks, and the large quantity of iron which appears to have been present then, seem to point to that time as the most probable age of the hæmatite in these districts.

The PRESIDENT: We have listened with pleasure to the elaborate communication of Mr. Kendall, and some very important questions are raised which are very difficult to answer.

A vote of thanks having been unanimously passed to Mr. Kendall, on the motion of Mr. AITKEN, seconded by Mr. CHARLES HARDWICK,

Mr. AITKEN said: I have, on several occasions, visited

Furness, and have paid some little attention to this matter, which has been discussed so elaborately by Mr. Kendall; but I confess I am not prepared to venture upon any theory as to the origin, or age, of the valuable hæmatite ores which are found in such vast masses in the Furness district. I have, however, listened with very great pleasure to the paper, and learned many important facts from it. One part, however, of Mr. Kendall's theory appears to me to be open to objection. As I gathered from the reading of the paper—which was rather difficult to follow in all its elaborate detail—Mr. Kendall's theory is that iron was contained in water which overflowed the carboniferous limestone of Furness, and that iron combined with the limestone enlarged the caverns or fissures in which the hæmatite was deposited. It struck me, as the paper was being read, that a difficulty presented itself in the acceptance of such an explanation, inasmuch as we do not find, generally, where carboniferous limestone exists—and where it must, I presume, have been also overflowed by the sea—we do not find deposits similar to those of Furness. We must therefore look, I think, to to some local agency operating in that particular district which has not existed in other carboniferous limestone districts, either in this country or in other parts of Europe. Iron is found in many places in connection with carboniferous limestone, sometimes interbedded with it in small bands, and at other times mixed with the rock sufficiently to give it a red colour; but, so far as my knowledge extends, we do not find it in anything like the same quantity which exists in this particular locality. Consequently, it seems to me we must look to some local operation of Nature which has acted in this particular locality differently from others. Mr. Kendall's theory, as far as I can gather, would apply to all other parts as well as to Furness. Whether the igneous theory of Mr. Binney is sufficient to account for the local agency to

which I have referred, I have not sufficient information to be able to say; but the one great objection to accepting that theory, to my mind, has always been that we do not find, in connection with this iron, which is to a large extent pure—and contains, I suppose, about 70 per cent. of iron—we do not find any volcanic products here, either in association with the iron itself or in the locality, except in the northern part of Furness, and which has, I believe, no connection with the iron. There are igneous rocks there, but I believe they are distinct and separate from the iron deposits. Consequently, difficulties present themselves to my mind which I am not able to reconcile. I have read several works treating on this subject, but have not yet heard any theory which perfectly satisfies me and fully accounts for the way in which the hæmatite has been deposited.

Mr. Dickinson: I have been in several of the principal mines in the districts spoken of—Whitehaven and Furness—and I think it would be unfair to enter upon a discussion until we have the whole of the paper, of which some portions were omitted in the reading, before us. Mr. Kendall seems to have gone into the subject with great fairness and with great deference to the opinions of others, on which grounds he is, I think, entitled to respect. Mr. Aitken seemed to take a very fair and full view of the subject. The formation and filling up of mineral veins and deposits is a subject which has not yet, to my mind, received the attention it deserves. People who have endeavoured to account for it introduce some physical operation—as the movement of water—as being necessary. We have had this explained by the drifting in of iron from the surrounding hills, and by infiltration; but the connection, sometimes to be seen in lead mines in the mountain limestone, existing—of a fine thread, not thicker than a piece of

worsted, between the vein and a side deposit—shows that there must have been some other mode by which those deposits have been formed than the simple drifting in of the iron, either from the hills or by water. There has been a deposition going on simultaneously with the formation of the rocks. In no other way could these deposits, which we find isolated in the middle of solid rock, be accounted for satisfactorily to my mind. Mr. Kendall, in the concluding part of his paper, set forth that the iron ore had been deposited simultaneously with the Coal Measures. Of that I think there cannot be any doubt, and the same is borne out not only by the districts now under discussion, but by the deposits in the Forest of Dean also, where they underlie the entire coalfield. Another point which seems to have been passed over rather lightly in the paper is the fact of the contiguity of the Permian. We find the Permian formation associated with, or not far from nearly every principal deposit of hæmatite that we know of. How the relationship has been established between the two can, to my mind, only be satisfactorily explained by the action—probably Voltaic first—which has communicated the iron from the Permian deposits to the limestone—(which seems to have had a greater affinity for it)—but how the deposits have taken place I shall not attempt at present more minutely to account for. The fact that the Permian is generally associated with all these mineral deposits is one which should ever be borne in mind, and will, I think, tend to the explanation of how the deposits were formed.

On the motion of Mr. Plant, seconded by Mr. John Knowles, the discussion was adjourned until the printed paper was in the hands of the members.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART IX. VOL. XIII. SESSION 1874-5.

At the ORDINARY MEETING of the Society, held on Tuesday, 23rd February, 1875.

Professor W. BOYD DAWKINS, F.R.S., President, in the Chair.

A list of donations was read, of the current publications, from the Edinburgh Geological Society, South Wales Institute of Engineers, Swansea, and the Sheffield Free Museum and Library.

The following gentlemen were elected Ordinary Members of the Society :—Dr. Bangay, Cheadle, Cheshire ; Mr. George Nesbitt Greenheys ; Mr. Joseph Hetherington, Shap and Dalbeattie Granite Company, Manchester.

The PRESIDENT said : Before we enter upon the business on the notice paper, I wish to refer to the very sudden death of Sir Charles Lyell, yesterday. He was one of the oldest Honorary Members of this Society, having been elected in 1838. It is almost superfluous for me to say anything about Sir Charles Lyell's career in the scientific world, we all know of his great eminence by his books. He was distinguished in many—I may say in nearly all—the fields of geological investigation, and of physical geography, and his untiring industry was unabated to the last. He was born in Kinordy, in Forfarshire, in the year 1797, and was seventy-seven years of age.

I have also to mention the decease of Mr. R. Hyde Greg, of Norcliffe Hall, Cheshire, who was one of the founders of this Society in 1838. He was for many years a successful manufacturer and a distinguished man in all the great municipal and political movements in Manchester. He was one of the most zealous advocates for the encouragement of education to the working classes, helped to establish the Manchester Mechanics' Institution, and did much in his early days for the spread of a study of science, and especially of geological investigations. His son, R. P. Greg, F.G.S., has acquired a lasting reputation for his excellent "Manual of the Mineralogy of Great Britain and Ireland," published in 1858. Mr. Greg closed worthily a useful life at the ripe age of eighty years.

I am sure the members will feel regret at the loss of two of its old members, who, thirty-seven years back, helped, with others, to found this Society, and of which so few as twelve are all that at the present time are to be found in the ranks of its members.

The President drew attention to the issue of a new Catalogue of the Library, which had been compiled by Mr. J. Plant, one of the Honorary Secretaries.

DISCUSSION ON MR. KENDALL'S PAPER ON THE HÆMATITE DEPOSITS OF WHITEHAVEN AND FURNESS.

The President said: The first subject to be discussed to-day is the paper which was read at our last meeting, and has since been published—that by Mr. Kendall, on the Hæmatite Deposits of Whitehaven and Furness. It is a paper full of important points, and is one of extreme value.

I do not know that such a philosophical paper, on that sort of subject, has before been brought before this Society.

Mr. William Brockbank, F.G.S., said: Mr. Kendall, in his paper published in the "Transactions of the Manchester Geological Society," part 8, vol. XIII., has taken exception to some of my published opinions as to the origin of hæmatite ores. I purpose, therefore, briefly to examine his own theory, and to state as shortly as possible my own views in reply

Mr. Kendall's theory may shortly be stated as follows:—(1) The sandstones and shales of the Coal Measures contain a large percentage of iron. (2) Those rocks probably overlaid the whole area now occupied by the limestone which contains hæmatites. (3) The iron they contained was dissolved by carbonated water permeating the rocks, and this carbonated solution thus carried down attacked the underlying limestone and deposited the iron on its lines of faults and meridianal planes.

(*a*) Now it can readily be shown that true hæmatites are found in situations where these conditions could not have obtained, and altogether beyond any influences arising from the Coal Measures; and therefore we cannot account for the presence of hæmatites by this theory. For instance, in the porphyry of Bowfell there are large veins of true kidney hæmatite ore, and especially in the hollow or cleft between its two summits. The pike of Bliscoe, in Langdale, is deeply veined with hæmatite, and Red Tarn, behind its summit, derives its name from the hæmatites which form its shores. Indeed, so rich are the veins of true hæmatites in the older rocks at the head of Langdale, that it has been in prospect to carry a railway up to work them.

There are true hæmatites near the summits of Scawfell. The Screes of Wastwater are veined with them. Red pike

on Ennerdale gets its colour and name from hæmatite ore, and in this locality it was smelted by the Romans. All these are in the syenite, porphyry, and other oldest igneous rocks. There are very rich mines now worked in clay slate at the foot of Grasmere, and there is a railway making up the Ravenglass Valley to convey the ore from mines which occur in veins in the granites and other older rocks in the Eskdale Valley. At Lindal, in Cartmel, a vein of hæmatite can be seen between the clay slate and limestone; and all round Arnside Knot are true veins of hæmatite, much altered by heat. These, then, are instances of the occurrence of hæmatite ores, directly from their parent source, and, in my opinion, they prove the origin of hæmatite ore to be igneous.

(*b*) In considering the origin of the hematite ores as they are now found, it is of great importance to endeavour to carry ourselves back in thought, to the time at which they were thus deposited; and to consider what would be the position of the rocks in which they were received.

(*c*) Supposing, for example, that we take it for granted (as I fully believe we may), that the period in which the hæmatites abounded and were largely produced, was that of the close of the Carboniferous and commencement of the Permian era, and bearing in mind that the Carboniferous Measures were deposited horizontally, and afterwards tilted at a high angle, then denuded and again sunk below the level of the sea before the Permian era commenced, (because the Permians were deposited unconformably upon them), we must see at once that there is room here for vast changes—by gigantic forces such as have no parallel with us, and which would occupy a long epoch of time from first to last.

(*d*) Now, if we are correct in our assumption that the hæmatites were developed during the earliest Permian era, it follows that the rocks in which they now are found were

then below the surface of the sea. I believe that the hæmatites were poured out into the Permian ocean, just as we read a few years back, that during an eruption of Mauna Loa, in the Sandwich Islands, the ocean was coloured red for miles around by the ferruginous mud which the volcano then poured into it.

(*e*) It can be shown that at this time the clay slates of Dent, in the Whitehaven district, were undeveloped; because the Permians now rest in detached masses both upon the Skiddaw slates, (near Stocksbridge) and green slates (south-east of Mousegill), so that we may picture to ourselves, seawards, a series of carboniferous reefs, resting upon the syenites and porphyries of the Lake district.

(*f*) Now, Professor Phillips describes the great igneous granitic and syenitic masses about Scawfell and Bowfell, as having been in fusion since the deposition of the clay slates; because the latter are everywhere found to be indurated and metamorphosed by their action. It is these very igneous rocks which now bear the hæmatite veins above described, and we thus have a direct clue to the origin of the rest. Bearing in mind that the clay slates of Dent were not yet above the level of the ocean, we may picture these igneous centres, pouring out the ferruginous stream of lava-like matter, seawards, where it would meet the carboniferous rocks, tilted and fissured, and thus fitted to receive it. Then followed the Permian era, and after long ages the great final upheaval, by which the outliers of the Lake district, Dent Fell and Cold Fell in the Whitehaven district, Black Comb in the Millom, Ireleth and High Haulme in the Furness district, were pushed through, tilting the carboniferous rocks, and again fissuring them in all directions. This, again, would not be the work of a moment, but it would in all probability occupy an epoch, giving time enough for denudations and for the wearing out of the subterranean

water courses or caverns, which became filled with the hæmatites wherever the circumstances were favourable.

(*g*) And lastly, followed the Glacial epoch, when the ice planed down the rough surfaces, grinding the rocks into till clay, and moulding the surface into its present form. I will not trouble the Society with a description of this part of my subject, because it has been fully treated in the papers, which will be found in the Proceedings of the Literary and Philosophical Society*, and to which opinions I adhere. Mr. Kendall only cites from the last, which described some glacial evidences in the Furness district; but an earlier paper described an equally striking example in the Whitehaven district, and I believe we can only account for several of the great superficial deposits by the glacial theory.

Mr. J. E. Forbes read a note from E. W. Binney, Esq., F.R.S., saying, "It appears that Mr. Kendall has not read my papers on Hæmatite iron, which can be found in the Proceedings of the Literary and Philosophical Society of Manchester.†

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* Proceedings Lit. and Phil. Society of Manchester:—

Dec. 10, 1867, "On the Origin of Hematites."

Dec. 1, 1868, "On the Glacial Action in the Whitehaven District."

Nov. 10, 1870, "Notes on Glacier Moraines, &c."

Feb. 18, 1873, "Glacial Action, Furness District."

† "Glance at the Geology of Low Furness, Lancashire."—Transactions Lit. Phil. Soc. Man., vol. 8 n. s. p. 443.

"The beds of iron appear to have been formed after the deposition of the carboniferous limestone, and before the deposition of the upper new red sandstone—the limestone rock, in some instances, seems to have been fissured, but in others eroded, or water-worn before the introduction of the iron. During the formations of the old red, as well as of the new red sandstone, a vast amount of peroxide of iron appears to have been mingled with the waters of the ancient ocean. But still the quantity in the iron mines of Low Furness is such as to indicate a proximity to the source from whence it originated. It appears to have been thrown up by volcanic action, and then carried by some means, into the valleys and fissures where it is now found. But whether the iron was injected into the places where it is now

Mr. Plant: I have carefully read Mr. Kendall's most excellent paper, and I believe, notwithstanding all that Mr. Brockbank has advanced, in his published papers and now reiterated to the meeting, that the view taken by Mr. Kendall is a very sound one, and quite in harmony with those views which the leading Geologists hold in the United States, in respect to the true origin of hæmatite ores. Professor J. S. Newberry, Geologist for the State of Ohio, writing upon "The Hæmatite Ores of the United States," says:—"The deposits of this ore which occur in the United States are second to none in quality and quantity, the most important of these are found in the iron regions of Marquette, Michigan, and in that of central Missouri, the geological age of these districts is apparently the same—

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met with, through the fissures immediately below, or was first mingled with the waters of the sea which then flowed through the fissures and caverns of limestone, and gradually filled them up with the metallic matter, held partly in solution, as Professor Sedgwick thinks, is difficult to determine. The neighbouring district towards the mouth of the Duddon and Black Coomb, show abundant proofs of having been formerly much disturbed by volcanic agency."

"On the Origin of Ironstones."—Trans. Lit. Phil. Soc. Man., vol. xii., n.s., p. 40.

"After examining the beds of hæmatite found in the carboniferous strata in regular beds, as in the vicinity of Whitehaven, and those at Ipstones (Staffordshire), ... "no one can scarcely doubt but that they had their origin in volcanic vents, and flowed into the waters of the sea, where they were deposited with the argillaceous and siliceous impurities found associated with them, layer by layer, like any other substances thrown down from suspension. This is evident from the beautifully laminated structure of the Ipstones bed."

"The vast deposits of hæmatite, in the north of Lancashire, in the Hundred of Furness, occur in the great clefts of the carboniferous limestone, these no doubt, from their great purity, being but little mixed with foreign matters, had their origin from volcanic sources, on or near the spot where they are most found. Some of them, probably, may have come up through the bottom of the clefts in which they occur, and others from a short distance, and flowed with water into their present positions."

viz., Huronian. On Lake Superior it is easy to see that the ore beds were *once horizontal strata*, deposited in conformity with many other stratified sediments, but they are now folded and broken in such a way that their true nature was for a long while misunderstood. Like the magnetic ores of the Alleghany Belt, *they were once considered eruptive*, but the progress of modern science has shown that they are simply metamorphosed strata, once deposited horizontally, like the sheets of iron ore in the unchanged Palæozoic rocks of the coal measures." These deposits of hæmatite extend over an area of about 120 miles from east to west, but have been greatly eroded, and are now left in isolated masses, lying for the most part in synclinal troughs.

The analyses of the Whitehaven and Furness hæmatites given by Mr. Kendall, are almost identical in their elements with those of Lake Superior and Jackson Mine, viz. :—

	Per-oxide Iron.	Pro-toxide Mang.	Lime.	Mag-nesia.	Carb. Acid.	Phos. Acid.	Sulp. Acid.	Silica.	Alu-mina	Metallic Iron.
Whitehaven, Cleator Moor	95·16	0·24	0·07	..	..	trace	trace	5·66	0·06	66·61
Furness, Gill Brow	86·50	0·21	2·77	1·46	2·96	trace	0·11	6·18	0·30	60·55
Lake Superior, U.S.	79·80	trace	0·57	0·24	..	0·14	0·02	9·82	1·64	60·69
Jackson Mine, U.S.	93·75	trace	0·61	0·23	..	0·32	0·03	8·27	0·73	65·62

In describing the characters of the varieties of iron ores of Central Missouri, Professor Newberry says:—" Red hæmatites consist mainly of peroxide of iron, the ores of which have been plainly derived from limonite—brown hæmatite—by the loss of the combined water. The famous Cumberland ore of England is a typical example of this variety; this was once a hydrated sesquioxide deposited from water in concretionary masses and having a fibrous, radiated structure, similar ore is found in various parts of the world, wherever, indeed, a limonite has been subjected to metamorphic action, by which its water is removed; hæmatite

is found in concretions or botryoidal masses in sand or clay, filling crevices, pockets, and basins, or incrusting slopes—wherever, indeed, chalybeate waters have precipitated its iron. It is often associated with limestone rocks, because they are, more easily than others, dissolved by atmospheric water, so as to form caverns and galleries where the ore may accumulate, and also because the limestones sometimes contain much iron, and in the removal of the carbonate of lime by solution, the oxide of iron is left, and, to a certain extent, takes its place."

Sir H. de la Beche, ("Memoirs of the Geological Survey," Vol. I.) in a description of the rocks in South Wales, describes in detail the occurrence of a layer of hæmatite interbedded in the carboniferous rocks. The section is found at Purlieu, Forest of Dean, and shows a mass of stratified sandstones, shales, hæmatite, and limestone, as follows:—Sandstones and shales, 88 feet; limestone, 90 feet; limestone with hæmatite, 60 feet; limestone, 330 feet. In this instance, the view advanced by Professor Newberry is fully supported as to the interbedded occurrence of hæmatite. Another authority for the chemical alteration of ordinary clay ironstones into limonite, göthite, and compact hæmatite, by the metamorphic action of infiltrating water, will be found in an article by Mr. E. T. Hardman, of the Geological Survey of Ireland.*

To my mind, the origin or these red hæmatites may be clearly traced to metamorphic action induced by water, and I think Mr. Kendall has conclusively proved that in the Furness district the hæmatites furnish not one particle of proof that they were the result of igneous action, either remote or contemporary in time, with the hæmatites.

* Trans. Royal Geo. Soc. Ireland. May, 1873.

Mr. Brockbank: I agree in every word that the United States Geologist says. The way I have described it is thus: the masses as we now find them are the result of ferruginous matter poured into the sea. You will readily see that if a hot ferruginous lava falls into the sea it is at once dispersed, and its constitution is altered. It falls like the hot slag from a blast furnace, when run into cold water it would become broken up into a fine powder and would thus fall to the bottom of the Permian ocean, and we should consider it thereafter as a Permian deposit; there are veins of hæmatite on Bow Fell, which show that the origin was igneous, then there is evidence elsewhere of its having been re-deposited in water.

The President: The view which Mr. Kendall has urged before us with so much force, and which has met with such an able—I won't say opponent, as Mr. Brockbank, is one which commends itself to my mind. If you examine Mr. Kendall's paper, page 262, fig. 17, you will see an important section, in which two beds of shale are continued from the limestone on one side of a vein of hæmatite through the hæmatite into the limestone on the other side without being altered in the least. That section proves, to my mind, that the space now occupied by hæmatite was occupied by limestone originally. Nor can it be doubted, that the cause by which the space is now occupied by hæmatite was a chemical and not a mechanical one, simply because, if it had been mechanical, these two layers of shale, which are continuous across, from side to side, would not now have been there. In that case, the whole of that hollow would have been swept out bodily. Now the next point is: do we know of any chemical cause capable of producing that change now? About that there cannot be two opinions. Supposing that you have bicarbonate of iron in contact with carbonate of lime, what do you get? You simply get the carbonate of

lime exchanged for carbonate of iron, and that carbonate of iron, by a series of changes and metamorphoses such as Professor Newberry mentions, would become hæmatite.

It seems to me that the igneous origin of the iron does not render Mr. Kendall's view untenable. It is undoubtedly true that in the Permian age there were vast volcanic ejecta in Cumbria, Scotland, Ireland, and other places; and it is very probable that those igneous out-bursts would cause the accumulation of a vast quantity of iron, which might subsequently be introduced into some of these places, just as Mr. Kendall has described. For my part, I do not see any discrepancy between the views which Mr. Brockbank has advanced and those which Mr. Kendall upholds: it rather seems to me that Mr. Brockbank's facts would explain the sources of the iron, whilst Mr. Kendall's view would undoubtedly explain—and, so far as I know, no other view has ever yet explained—the presence of iron ore in such a state as we find it. Of course, in some cases, supposing Mr. Kendall's view to be true,—supposing we have an antecedent hollow, or a cave, traversed by water charged with iron, a sort of iron stalactite, or kidney iron ore would be formed. For my part, I am fully inclined to believe that Mr. Kendall's chemical view is probably true; and I further believe with Mr. Brockbank that the probable source of the great bulk of iron has been these igneous outbursts. In the basalts, a considerable quantity of iron occurs, and it is probable no doubt that the iron there present is partly that which has found its way eventually into such accumulations as these.

Mr. G. C. Greenwell: I have formed an opinion as to the probability that all the hæmatite ores, or at least the great bulk of them, originally existed in the form of

carbonate of iron. I was told, during a recent visit to Gloucestershire, that such had actually proved, in a very notable instance, to have been the fact. A brown hæmatite—it cannot be called the pure red hæmatite,—has been worked at Iron Acton: and they have, in prosecuting that vein downwards, got into bicarbonate of iron.

Mr. Joseph Dickinson: I think, in criticising Mr. Kendall's paper, we should rather thank the writer for having given us such a collection of facts, deduced from his own observation, than expect him to have read every paper that has been read at the meetings of the Literary and Philosophical Society. With reference to some of the observations which have been made to-day, as to the hæmatite having been originally ejected from volcanoes, there is one startling fact which, to my mind, requires to be got rid of; there is no hæmatite with which I am acquainted which is magnetic. Now, if you subject hæmatite even to a very moderate amount of heat, it at once becomes magnetic. How the theory of the ejection of the iron in a molten state, from a volcano, is to be reconciled with that fact I cannot perceive. The observations which I made at the previous meeting, when the paper was read, indicate the views which I hold on the formation of metalliferous deposits. For many years I have discarded the prevailing geological view of their having been carried or thrust into fissures either by water or volcano from some imaginary source, either above or below. I know what the geological views are, and am often pleased to hear and read the ingenious theories accounting for the formations as we find them in the earth. The changes which are going on by the action of water, air, and volcanoes are undoubtable, and perhaps in no instance are they more apparent than in the important subsidences which have occurred, and are now occurring, from the solution of

rock-salt. My faith, however, is not so strong as to reconcile the views that strata of the thickness of several miles have, as is supposed, been swept away either by the action of water on the surface of the earth or by an iceberg acting as a gouge to chisel out when the denudation (as in the case of some of the lakes) is below sea level, with nothing but a few conglomerates or other totally dissimilar strata, such as chalk, to be assigned as the product of what has disappeared, with no recognisable resemblance either to the antecedent strata or to the drift which covers the present surface on nearly all low elevations. Some years, ago I explained to this Society the cosmic views which I hold, attributing the principal apparent changes to anterior causes when the whole of the planetary system was being matured, by which all the important features now geologically attributed to denudation, upheaval, and such like, are to my mind much more satisfactorily accountable. Since I then announced my adherence to these old views, prismatic analysis (one of the most interesting discoveries of the age) has shown that the solar system is of the same material as this earth. This discovery, I need scarcely say, has strengthened the opinion which I had previously entertained from the evidences of the strata and covering drift only.

The extensive vertical displacement of strata by faults amounting in one instance, in the immediate neighbourhood of Manchester, to 1000 yards, without any corresponding alteration to be seen on the surface. The fossils, whether of shells, fish, or plants, with their water habitat, and the reptiles with a like habitat for at least some period of their life, all bear witness to strata having been formed in water, and the faults, the cleavages, the contortions, the trap rocks, whether in dykes or partially stratified masses contiguous to dykes, from which they have apparently flowed, all agree in

showing that the stratifications, when they were being formed, were in a plastic state. All change did not then cease. The great change took place before the planet took its orbit, but the smaller changes to which I have alluded are still going on, and the crystals, which may be seen still forming in modern workings in mines where the process is not interrupted, show that subtle change is still in operation.

It is by a view of the whole subject that the key is to be found to unlock the secrets under which the metalliferous deposits were formed and are being transposed. As I lately read in *The Mining Journal*, from a lecture by Professor Gladstone in explaining chemical affinity, silver is replaced in its salts by mercury, mercury by copper, copper by tin, tin by zinc, zinc by magnesium, magnesium by sodium. At the first moment, as he puts it, the action must be conceived as purely chemical, but after the first particles of the second metal have been deposited it becomes also voltaic. The current passes from the one metal to the growing and branching crystals of the other metal, and the liquid between is also placed in a peculiar competition of change, as the metallic particles arrange themselves symmetrically in one place, and their new partners enter into a new combination in another. I stated at the previous meeting that most of the principal deposits of hæmatite iron- ore are near the Permian and new Red Sandstone formations, which are impregnated with iron sufficient to supply the deposits; and if I had time I could accumulate many other confirmations, such as the ryder or gossan, found in the upper part of mineral veins, and the way in which limestone, where a mineral vein passes through it, is found replaced with iron sometimes for several yards from the vein, and the connection by a thread which exists between a vein and a churn, or side flat of lead ore, as found in the mines of Cumberland, but I have said enough to indicate how, in my

opinion, the mineral deposits have been formed and are being transposed.

Mr. AITKEN: It was not my intention, having spoken on this subject when Mr. Kendall's paper was read, to have occupied the time of this meeting, hoping, as I did, that certain points which seem to have escaped attention would have been spoken of by others. I must express my admiration of the valuable paper which Mr. Kendall has laid before this Society, and my opinion that in presenting it to us he has laid the Society under a great obligation. In it he has not only furnished us with a most valuable and important body of facts,—such an array, indeed, as has not previously been brought together, in any one paper on this most interesting subject; but he has also reviewed the various theories that have been advanced by geologists who have paid attention to the subject for many years past. He discusses the aqueous theory, and I think, shows conclusively by argument and fact, that it is not tenable as it has hitherto been advocated. The igneous theory he also disposes of in an equally satisfactory manner. To-day, we have had present Mr. Brockbank,—a gentleman who has advocated the igneous theory,—and, so far as I understand Mr. Brockbank's previously expressed opinions, they are these: that iron, almost in the state we now find it, was ejected from volcanoes, in great masses; that it fell into the ocean and was dispersed; and that it was eventually carried, by ice or by aqueous action, into caverns previously existing in the carboniferous limestone. The objection to that is, that nowhere do we find iron of the same purity as we find it in Furness. In no part of the world do we find that volcanoes eject such materials; consequently there is necessitated the intervention of some chemical operation, subsequent to the volcanic outburst; and Mr. Brockbank has not established his position, at all events, to my satis-

faction. I am aware that Mr. Kendall in discussing this matter, has omitted reference to the papers read some time ago by Mr. Binney, and referred to by that gentleman in his letter read to-day. Mr. Binney, as far as I understand,—I speak subject to correction, not having read the paper recently,—takes the ground that in volcanic eruptions masses were thrown out containing a large percentage of iron; that this iron by subsequent chemical action became decomposed; and that the ore was carried into fissures and caverns. It strikes me if we were to combine the theories of Mr. Kendall and Mr. Binney, we should come more nearly to accounting for the way in which these hæmatites have been produced, than is possible, perhaps, by either theory standing alone. If we take the volcanic ejecta,—which occurs on a large scale in the Lake district, and even as far south as the northern part of Furness—and suppose, what I believe is perfectly true, that these ejecta contain a large proportion of iron; if these were acted upon by water and by the atmosphere; if they became mixed in the ocean, and were afterwards carried down, as Mr. Kendall describes, you might have produced that chemical action to which you have alluded. The two theories combined certainly explain more of the phenomena than, to my mind, can be explained by any one of the theories taken separately. One point has not been mentioned in the discussion to-day, which bears strongly in favour of Mr. Kendall's supposition: it is, that in some parts of Furness—at Lindal Moor, perhaps, more particularly—we find a considerable number of fossils imbedded in the hæmatite; and these fossils are themselves converted, in some cases, into pure hæmatite—in other cases only partially so. If, as he states, the bicarbonate of iron came in contact with the carbonate of lime and decomposed it, setting free the carbonic acid, we should have a wasting and wearing

away of the limestone. The fossils embedded in the limestone, containing more silica than the body of the limestone, would be less acted upon by the carbonic acid, and therefore would be preserved longer than the limestone; and these fossils would eventually drop out and become embedded in the sesquioxide of iron which is eventually produced. I have put upon the table a few of the fossils obtained from Lindal Moor, which you will see, on examination, are all of carboniferous limestone age. You will find one or two of them pure hæmatite, and I think that these show pretty conclusively, at all events, that these fissures could not have been filled up by bodies of molten iron, nor yet is it probable that the iron could have been carried in, as has been suggested, by icebergs or water. There is one other fact mentioned by Mr. Kendall, but not adverted to to-day, which strongly bears out this theory, I think, and that is the intimate connection which exists between the limestone and the iron. Mr. Kendall states that in many places it is not possible to separate the two—that if you strike off a piece of hæmatite you bring away also a portion of the limestone; on striking off a piece of limestone, a piece of hæmatite comes with it. Here is a specimen which I obtained in that district, and you will see that statement borne out by it. It seems as though a transmutation had taken place. The weakest part of Mr. Kendall's paper is his mode of accounting for the occurrence of iron. With that I entirely disagree. He seems to attribute it to the Coal Measure period, when he assumes Furness was covered by a thick mass of shales, charged with a very large quantity of iron. Now, shale is not permeable by water, or only very slightly so. Mr. Kendall recognises this as a serious difficulty in the way of the iron contained in these shales being carried down to the limestone, and introduces the supposition that large faults occurred

through which the water was conveyed, until it came in ontact with the limestone below. Now we know that, in most cases, faults are filled with clay and other impermeable substances, and it seems to me impossible that any large quantity of water could find its way down through those faults and it certainly could not penetrate the compact masses of shale such as we see in Coal Measure strata, even if rocks of this character ever overspread this area, which is extremely doubtful. I think Mr. Kendall, in that portion of his paper, has not established his theory.

Mr. G. C. Greenwell, F.G.S., then read a paper on "Basalt."

ON BASALT AND ITS EFFECTS.

By G. C. Greenwell, F.G.S., M. Inst. C. E.

As I am not acquainted with any instance of the occurrence of basalt in the coalfields of Lancashire and Cheshire, and as I have had several opportunities of examining this rock, I think that a paper upon the subject will be of interest to the Society.

"The term basalt (according to Lyell, "Elements of Geology," p. 593,) has been generally applied to any trap rock of a black, bluish, or leaden-grey colour, having a uniform and compact texture. Most strictly, it consists of an intimate mixture of felspar, augite, and iron, to which a mineral of an olive green colour, called olivine, is often superadded, in distinct grains or nodular masses."

Trap rocks are of volcanic origin, and are similar in their composition to many lavas, which are basaltic, as in Vesuvius and Auvergne (Lyell).

The colour of basalt is generally greyish black passing into ash grey, brownish black and bluish black; its fracture is coarse or fine grained, uneven or fine splintery: it is

amorphous, or tabular, or in columnar angular concretions from a few inches to 200 feet in length; usually articulated, the articulation being formed by the convex end of one piece implanted in the concave end of the next: it is also found in globular masses composed of concentric lamellæ of various sizes up to several feet in diameter. It is nearly equal in hardness to common glass, but possesses a degree of toughness which renders it difficult to be broken. It is scratched by the knife, giving a light grey streak; its specific gravity is from 2·86 to 2·97. It is magnetic; I have examined eleven specimens, and found their degree of magnetism to vary much: it is only a portion of the powdered material that is attracted by the magnet, and it is therefore probable that any magnetism in basalt is attributable to oxide of iron mechanically mixed with it.

It melts with ease before the blow-pipe, without addition, into a black glass.

The following is an analysis of the basalt of Staffa (which is similar to that of the Giant's Causeway), by Dr. Kennedy:—

Silica..	48
Alumina	16
Oxide of Iron	16
Oxide of Manganese	0
Lime..	9
Magnesia	0
Soda	4
Moisture and volatile matter	6
	99

The chief British localities of basaltic rocks are, the Highlands of Scotland, Edinburgh, Northumberland, Durham, and Dudley; they form the Giant's Causeway in Ireland. I shall now proceed to the description of basalt

and its effects, as seen in some of the above localities; and first of the basalt of the Highlands of Scotland, and of Edinburgh.

In the second volume of the Transactions of the Geological Society (1814), there is a contribution by Dr. MacCulloch, "on the junction of trap and sandstone at Stirling Castle," in which the author says, "that he has been induced to preserve this notice and drawings of it, partly on account of its decided and clear disposition, and partly, lest the same operations by which it was first exposed may, at no distant period, again remove or overwhelm it;" and that, "it was in cutting a new road through the Castle hill, that the appearance in question was laid bare."

The trap stratum here consists of a dark bluish black compact greenstone where it is in contact with that part of the sandstone stratum which is exposed.

The sandstone bed itself consists of different laminæ, varying in colour, but generally slate coloured, yellowish, and grey. The thinner beds are separated from each other by laminæ of a clay slate, very much confounded with the sandstone, and those two substances alternate frequently and irregularly till they approach the thicker beds, which lie in contact with the greenstone (basalt). As they approximate to it, they become more indurated and assume a texture approaching that of hornstone: it is here of an ochre-brown colour: its fracture is conchoidal or splintery, with an even shining surface and the thin fragments transmit light. Dr. MacCulloch further remarks the resemblance which this change bears to that gradation from sandstone to a jaspideous rock, which occurs in a similar situation at Salisbury Crag.

In the same volume, (p. 388,) is a paper by Dr. MacCulloch, entitled, "Miscellaneous remarks accompanying a catalogue of specimens transmitted to the Geological

Society," in which there is mention made of a noble façade of columnar trap, which, on the north side of the island of Gariveilan, near Skye, descends perpendicularly and without a break into the sea, rising to an estimated elevation of 200 feet. This, says Dr. Maculloch, in picturesque effect and in continuous profundity of shade, excels even the celebrated cliffs of Staffa. The columns are neither so regular nor so perpendicular as those of Staffa: a few here and there present nearly the same degree of regularity as those well known specimens on the south side of Arthur's Seat, at Edinburgh.

This colonnade towards the west is so elevated as to allow an examination of several strata which lie beneath it. The lowermost bed is a dark purple hornstone, of which the thickness cannot be determined, as nothing is seen below it.

Immediately above this lies a bed of rock about 20 feet in thickness, which is formed of globules, everywhere adhering together, which are occasionally compressed as if by a superincumbent weight, but are in many places absolutely spherical.

This bed is covered by one of trap or greenstone, forming a parallel bed of a more considerable thickness; it weathers so as to exhibit distinct globular concretions, although in its entire state the eye can trace no difference between the amorphous portion and the columnar mass above. This very common fact (observes Dr. MacCulloch) should serve to convince us how little information we can obtain of the true and fundamental structure of rocks from their natural fracture while in a state of integrity.

In illustration of this, I may take the iron ore of the coral rag which is found at Westbury, in Wiltshire; when this ore is covered by the Kimmeridge clay, it is a compact amorphous greenish rock, but when cropped up, so as only to be covered by two or three feet of light soil it is so far

disintegrated (having become peroxidized also) as to be a loosely coherent, oolitic, and ochry brown mass, which can in some cases be crushed between the fingers.

This bed of trap is followed by a bed of siliceous shale or flinty slate; considered by Dr. MacCulloch to have been an argillaceous shale, altered and indurated in consequence of its proximity to greenstone.

The last bed is the immense mass of columnar trap already mentioned, which surmounts the whole. The character of this rock is not that of a greenstone, but an obscure mixture of hornblende, felspar and quartz.

In volume V. of the Transactions of the Geological Society (p. 369) is a paper by Earl Compton, "On the rocks which occur along a portion of the south coast of the Isle of Mull." This paper describes some basaltic dikes and columns, but I quote it most particularly on account of the following passage:—

"Between the House and Carseg, and the three whin dikes, there are, under high water mark, rocks on the shore of a very dark colour and micaceous texture containing *Cornua Ammonis.*"

My reason for making this quotation will be found further on.

In the VIIIth volume of the Proceedings of the Geological Society, (Quarterly Journal,) Professor Nicol, (p. 417,) in referring to Dr. MacCulloch's map of Scotland, doubts the accuracy of the representation that there is any lias in that part of Cantyre near Campbeltown.

The occurrence of lias, however, in connection with the basalt of this period is too frequent to render it so very unlikely to be found here. From the great similarity there is in the basaltic deposits and phenomena of the west of Scotland, as observed in Mull, Staffa, Gariveilan, and other places in Scotland, it seems at least probable that they

were all the result of one action; and that the basalts of the north of Ireland were of the same date. And this date was posterior to that of the deposition of the chalk; as is clearly shown at Dunluce, where the basalt lies immediately upon it.

Salisbury Crag 550 feet, and Arthur's Seat 822 feet, above the level of the sea, are situated immediately to the east of Edinburgh; they are prominent examples of the extensive trap formations of Mid-Lothian, which occur in the neighbourhood of the city.

Salisbury Crag is formed of a mass of trap which has risen up and flowed over carboniferous strata, and in some places is overlaid by them also, showing that the trap has, as in the case of the whin sill of Teesdale, been interposed as a semi-stratum between portions of the pre-existent strata.

In the case of the whin sill it is interposed between the strata of shales, sandstones and limestones of the carboniferous formation. A similar intrusion of trap occurs in the coal measures of Ayrshire. The sketch (Fig. 1.) shews the position of the basalt and the coal strata at Salisbury Crag. There are here fine examples of columnar arrangement; the columns vary in length, thickness, number of their sides and position; those of the upper portion of the mass being inclined at a great angle, while those of the lower part are horizontal.

At the base of the basalt, a fine terrace walk has been excavated by cutting out a portion of the upper part of the slope, formed by the more perishable material of the coal and limestone shales; and this enables the junction of the basalt with the coal strata to be distinctly traced and examined.

The basalt of Salisbury Crag is usually a compact greenstone: near the south extremity of the Crag, both trap and carboniferous strata are thrown down about two feet by a fault, adjacent to which the greenstone is very dark in colour

and has the appearance of having again been subjected to heat, as it is more crystalline in its texture, the crystals apparently consisting of hornblende. In the shale beneath the basalt in some places are both balls and thin bands of clay iron stone, both of which are in a red calcined state; in another place and immediately contiguous to the basalt, is a bed of shale and sandstone mixed; calcined red, and converted into a substance with a glistening and semiconchoidal fracture and of the character of jasper; this is probably the sandstone described by Dr. MacCulloch, and above referred to. Under the basalt, there is, in another place, a whitish grey sandstone which has been indurated to a condition (allied to quartz rock), which does not admit of its being scratched by a knife; and again at another place there is beneath and contiguous to the basalt, a bed of arenaceous limestone almost as highly indurated, and of a rather bluish grey colour. On reference to the specimen of the red jaspideous rock alluded to, examination of it with a good magnifying glass reveals some singularly beautiful phenomena; it will be observed, that it is the siliceous rock that has been converted into the jasper, that side of the specimen being adjacent to the basalt: it will also be observed that there is a clear line of demarcation between the sandstone and the shale, although there is no parting between the two. The most beautiful appearance, however, is that of three or four minute alternations of strata, distinctly marked by the varied action of the heat upon the substances of which they are composed; and crossing these minute strata are tiny faults and dislocations, as perfect in their form, and as distinctly to be traced, as though the strata exposed were hundreds of feet in thickness, and the faults, hundreds of feet of displacement.

The trap rocks between Salisbury Crag and Duddingstone Loch are different from the basalt of Salisbury Crag. I had not

time to make a careful examination of them, but, generally speaking, they are of a red colour: amygdaloidal and porphyritic: the amydaloid containing pebbles of quartz and crystals of common garnet. The porphyry is felspathic.

Before leaving the basalts of Edinburgh, I shall make a remark or two upon another locality in the Lothians, where I have recently had an opportunity of making a few observations. I now refer to the Garlton district, in the neighbourhood of Haddington.

The basaltic rocks here are again different in composition from those already described, and seem to be of a somewhat more earthy character. I might say, that they are, in all probability, not purely igneous, but that they are more of the type of what might commonly be termed grauwacke. They have somewhat of the crystalline character of basalts and their associated rocks, but the usual lava like structure is wanting. I have a specimen from Garlton of a grey greenstone which is porphyritic and contains crystals of glassy felspar. I have also another from Garvald, where the rock is undoubtedly such a tufa as might be obtained from any recent volcanic eruption. West of Garvald there are quarries of red sandstone, the beds of which at this point dip to the north-west, and either pass under or abut against the rocks above mentioned.

Traversing these igneous rocks, or rocks affected by igneous action, are several veins of greater or less importance, containing red and brown hæmatite, one of which is well developed and in progress of working at Garlton. The direction of this vein is about 30° east of south, and runs in the direction of Chesters quarry, (working ordinary whinstone for road and building purposes,) towards Garvald.

The hæmatite, where worked, is of an excellent character, and the vein varies in thickness from a few inches to eight

feet: the vein underlies or dips to the north-east, at an angle of about 75° with the horizon. The ore is botryoidal and radiated. In the quarry at Chesters are some thin strings of brown hæmatite of fine quality, and there is a small quantity of white carbonate of iron also. I am induced to believe that where brown hæmatite is found in veins, the prosecution of these veins downward would lead to the discovery that in many cases they were originally veins of white carbonate of iron.

The next observations which I have to make upon basalts are upon those in connection with the carboniferous system of the north of England, in which locality we have whinstone, as it is locally termed, or basalt, in a great variety of interesting forms.

It properly however divides itself into two classes:—

First. Where it is found in the condition simply of vertically intruded trap in the form of dikes or walls of basalt, without lateral spread.

Second. Where it is found in the condition of lateral intrusion or surface overflow.

Under the first head are included what, in the north of England, are known as whin dikes.

As I have already, elsewhere, given an account of the greater number of these, it is unnecessary, in a paper like this, to go into any minute detail; I will, therefore, merely confine myself to the description of general features.

Whin dikes are walls of basalt, in most cases vertical or nearly so, which have been injected through the strata: they are of very variable thickness, different dikes being of different thicknesses, and the same dike seldom preserving the same thickness for any very great length of range: they are rarely accompanied by any considerable up or downthrow of the strata on their opposite sides—they indurate the shales and sandstones in their vicinity and convert coal

where they pass through it, into a cinder of greater or less density. They usually contain a core, which consists of a confused debris, often of rolled stones and pebbles. The basalt of which they are composed is very similar in composition to those above described, and is usually of a dark grey colour and of somewhat coarse texture.

Unlike ordinary faults of mere dislocation, they commonly preserve a uniform course throughout a great extent of country. The largest in the coal field varies very little in direction from Cockfield in Durham, to Robin Hood's Bay in Yorkshire, a distance of not less than sixty miles.

The Cockfield dike is in all probability in connection with the great whin sill or basaltic deposit of Tees Force; it is traceable as a dike from the western limit of the Durham coal field at Hill Houses, by Cockfield Fell, Bolam and Preston in Durham, and by Langbargh to near Robin Hood's Bay, Yorkshire. Its general direction is E.S.E. and W.N.W.; the breadth is commonly about 60 feet as at Cockfield, Langbargh and Egton, but it diminishes to less than 30 feet at the eastern extremity, and to 7½ feet at Butterknowle colliery in the south-west part of the Durham coal field; at Bolam, after having risen through black shales, it expands over the surface, and rests upon the shale. The sides of the dike generally slope or hade downwards toward the north; at Cockfield, this slope is one in five, and at Langbargh, about one in eight. At Cockfield, the dike is traversed by a slip fault, a downcast to the south-east of 24 yards, by which the coal measures are thrown down to that extent, and the dike is diverted its full breadth of 22 yards, out of its regular course: this, I think, shews that here the slip took place subsequently to the formation of the dike.

Near Egton Bridge it stands up, a lofty wall, over the waters of the Esk, and beyond Silhoue Cross, it ranges along the moors like an ancient military road; but in a large portion

of its course, especially in the wide vale of the Tees, it is concealed by alluvial accumulations. It is usually of a darkish grey, and is chiefly composed of olivine, carbonate of lime, mesotype, and quartz; and it has occasionally a tendency to prismatic structure. The formations divided by the dike, where it approaches the surface, are mountain limestone near Middleton; coal measures at Butterknowle and Cockfield; magnesian limestone and new red sandstone, in the south of Durham, and north-east of Yorkshire; and lias, and oolite as it passes onward towards Robin Hood's Bay; shewing the protrusion to be subsequent to the date of the oolite.

The strata passed through by the basaltic dike are more or less altered when in contact with it.

At Cockfield, the Bitchburn seam of coal is much affected by the dike, the action extending to the distance of 50 yards from each side of it; near to the dike the coal is converted into a kind of concreted soot, and at the distance of 10 yards it is cindered—at 25 yards it is partly so, and it is 50 yards before the coal is in its natural condition.

The effect produced upon the coal of the Hutton seam by a whin dike at Haswell colliery (about seven miles east of Durham), is shewn by the following analyses made by Mr. H. Taylor.*

	Cinder Coal Adjoining Dike.		Coal Sixty-three Yards from Dike.		Haswell Hutton Seam.	
	Including Ash.	Deducting Ash.	Including Ash.	Deducting Ash.	Including Ash.	Deducting Ash.
Carbon ..	80·255	92·888	89·916	91·768	84·284	84·890
Hydrogen.	2·405	2·783	3·441	3·511	5·522	5·561
Nitrogen ..	1·170	1·354	2·129	2·172	2·075	2·089
Oxygen ..	·923	1·068	1·228	1·253	6·223	6·267
Sulphur ..	1·646	1·905	1·267	1·298	1·181	1·189
Ash	13·601	..	2·019	..	·715	..
	100·000	..	100·000	..	100·000	..

* *Transactions* of the North of England Institute of Mining Engineers, vol. iii.

At Berwick, on the Tees, the white sandstone is so much indurated as to be unfit for masonry. In Kildale, the shale has been quite bleached, and in some places converted into scoria, and the iron ore appears as a loose yellow ochre. At Egton Bridge, the blue lias shale is changed to a pale greenish yellow, and resembles jasper in hardness.

There are several other whin dikes in Durham and Northumberland, but the description of the Cockfield dike just given affords a sufficient illustration of their general features and effects.

Under the second head we notice trap or basaltic deposits which appear to owe their position to the intrusion of the same substance composing the dikes, and during its course of elevation from beneath, between or across strata previously in existence, and also to the overflow of the erupted material over large portions of the then surface of the earth.

We have a remarkable instance of intruded basalt in the pseudo-stratum, well known in the whin sill of the west of Durham. This bed is of various thickness in different places; at Cauldron Snout, a waterfall on the river Tees, it is nearly 60 yards; at Dufton Fell, it is not more than 15 yards, and at Hilton, in Westmoreland, it is about 8 yards thick; at Allenheads, it is 80½ yards in thickness.

That this bed of basalt is not conformable with the carboniferous series with which it is connected, in Northumberland, is inferred from its varying position, relatively, to certain well known limestones; thus, at Allenheads, according to Mr. Sopwith, the top of the whin sill is 16 yards under the Tyne bottom limestone and the bottom of it ten yards above the Jew limestone; whereas, according to Westgarth Forster, in another section it is only one yard under the Tyne bottom limestone and 24 yards above the Jew limestone; it will be observed that there is (exclusive

of the whin sill, which in the former section is 80½ yards thick and in the latter only 40 yards,) not much difference between the thickness of the ordinary strata between the limestones, this being in the former case 26 yards and in the latter 25 yards.

The late Mr. Nicholas Wood* says: "I am aware that by some the apparently detached masses of basalt, which cap several of the eminences of Northumberland, have been considered as overlying masses. On a more attentive examination, however, and particularly in reference to the connection of this basalt with the beds previously traced, and also with the inferior limestone beds, it will, I trust, appear not only that the basalt of the lead measures, commonly called the whin sill, ought to be considered as a stratum, keeping nearly a determinate place in the series, but that the whole of the apparently detached masses of basalt in the county of Northumberland, (except those occurring in the shape of whin dikes,) are attributable to this bed of basalt." I make the above quotation on account of the position of the whinsill being mentioned as "nearly determinate," and as going to prove the diagonal manner in which the ordinary strata are crossed. There is little doubt, I think, now, that the whin or basaltic dikes and the whin sill, and the overlying masses of basalt are all connected together, but I should be very unwilling to agree that these overlying masses were formed in the same manner as the whin sill.

I shall, as in the case of basaltic dikes, give one example of basalt in the form of a surface overflow, as seen at Gunnerton Crag, about five miles north of Hexham. (Fig. 2.)

The basalt, which is here extensively quarried for road material, is in the face of the quarry, about 23 feet in thick-

* Transactions of the Natural History Society of Newcastle-upon-Tyne, Vol. I.

ness, but since the deposit dips and the surface rises to the north-east, it becomes thicker in that direction. Near the entrance of the quarry, on the south-west, the bottom of the basalt is 7 or 8 feet above the floor of the quarry, and immediately under it is a stratum of shale, 5½ feet thick, which is slightly indurated and whitened, and at 3 feet above the bottom of the whin is a parting which for a short distance, contains a thin layer of shale which runs out at each end, and is, in one place, of the thickness of 12 inches. Immediately under the stratum of shale is a bed of blackish limestone partly altered and containing madrepores.

The thickness of the limestone is not observable; it makes very bad lime; it dips under the basalt and crops out again to the surface about 300 yards to the south. The shale resembles the "Pencil Bed" of Mr. Sopworth's section,* and the limestone probably corresponds with the Jew limestone of the same section. In that section the thickness of the pencil bed is 10 yards, while at Gunnerton it is, as stated above, but 5½ feet.

The basalt at Gunnerton is a compact green stone of a dark grey colour, much harder than that of Salisbury Crag, and not easily scratched by a knife. The shale is a light purplish grey, of very fine grain; it can be cut with a knife, and resembles slate pencil. The limestone is hard, sharp, and crystalline, and with difficulty scratched by a knife. The specimen shown may be compared with those of basalt, shale, and limestone, from Salisbury Crag.

The overlying basalt is very prominent at Ratcheugh Crag, about 2½ miles E.N.E. from Alnwick, and at about the same distance west from the sea at Boulmer; here the basalt is columnar, but its upper surface seems to be con-

* Transactions of the North of England Institute of Mining Engineers, Vol. XIII.

formable with the strata of limestone which lie immediately above it, the dip being the same, viz., at an angle of 14° in the direction of south-east. The sketch (Fig. 3,) shows the position of the basalt with respect to the carboniferous strata: immediately overlying the bed of basalt is a bed of limestone, 10 inches thick; for 4 or 5 inches above the junction the colour of the limestone is changed from dark grey to brown, and its texture is more compact and crystalline; this appearance gradually fades away in passing upwards, and at a distance of 6 or 7 inches from the junction the limestone assumes its usual characters.*

As regards the basalt (green rock) of the South Staffordshire coalfield, it is unnecessary that I should make any remarks. I merely recall the attention of the Society to the communication upon it made to them by Mr. Henry Johnson, of Dudley. ("Transactions," Volume VII.) The specimen of the basalt (Rowley rag,) now shown, is for the purpose of comparison with those from other localities; it is more compact and close in texture than any of those yet described, and harder than any of them with the exception of that from Gunnerton Crag; it is largely quarried as a road material, and extensively manufactured into setts, for road pavement.

I shall conclude this paper, which has already become somewhat lengthy, with some account of the basalt of the North of Ireland, which I have recently had an opportunity of observing at Portrush and at the Giant's Causeway.

The basalt here seems to belong to that class which is more or less stratified—it exists as more than one intruded bed, and also in masses overlying formations of different ages, from the coal measures at Fairhead to the chalk near

* F. Forster, "Observations on Ratcheugh Crag," Transactions of the Natural History Society of Newcastle-upon-Tyne, 1830.

Dunluce Castle*; thereby apparently maintaining its relationship to the whin dikes, whin sill, and overlying basalt of Northumberland and Durham, as well as to those of South Staffordshire and Scotland.

At Portrush, the basalt is apparently stratified in conformity with the lias, upon which it lies, and into which it is intruded. The lias shale, where in proximity to the basalt, is converted into a chert, so hard that it cannot be scratched by a knife, and from which, in consequence, it is impossible to separate the ammonites which it contains in great profusion. The basalt is variable in its character and is sometimes of a dull brownish colour, with small crystals of pyrites; sometimes of a grey and more crystalline texture; and elsewhere it borders on granite, occasionally containing olivine in great abundance: the specimens illustrate these characters of the basalt, and also of the lias, with its embedded fossils.

On the upper surface of a bed of lias, and in a space of 4½ square feet, I counted fifty ammonites, varying from 1 in. to 3 inches in diameter. Near Dunluce Castle, the road from Portrush to the Giant's Causeway rests upon chalk, of which the cliffs consist, and on the land side of the road is a quarry, from which chalk (or as it is called locally limestone) is worked; and overlying the chalk is basalt. The chalk abounds in flints with sponges (see specimens), it is rather hard and the flint is of a lighter colour than usual. The basalt is coarse, darkish coloured and crystalline in texture; can be scratched with a knife, but is hard, it is considerably magnetic, and much resembles that found near the 2 feet fault in Salisbury Crag, already referred to.

Passing eastward, the general character of the rocks changes, and on reaching the Giants Causeway we find that

* Griffiths: "Geological and Mining Surveys of the Coal Districts of the Counties of Tyrone and Antrim."

the Cliff, approaching 400 feet in height, consists mainly of basalt interstratified in places with layers or beds of a red oxide of iron, of an ochry character. The general section of the cliff may be gathered from the sketch. (Fig. 4.)

At the immediate base of the columnar basalt there is a deposit of red hydrated iron ore of fine quality. In Nos. 2 and 6 the quantity does not seem large, but in No. 4 the quantity must be very considerable; it is partially worked in the neighbourhood of Dunluce, and various explorations have been made for it about the Causeway, but its position seems to render it unavailable at present.

The Causeway itself is a platform projecting into the sea. It has a rough and irregular surface, consisting of truncated basaltic columns; these vary in size and also in shape, and none of them that I measured were regular polygons. (Fig. 5.)

An irregular octagonal column measured in one diameter, from side to side, 24½ inches, and in another 19½ inches. The columns are jointed at varying distances of 2, 3, or 4 feet, the joints being at right angles to the axes of the columns; sometimes the plane of the upper portion of the column is convex, fitting into the concave plane of that on which it rests, and sometimes the reverse.

In many parts of the range the basalt consists of rounded concretions, which, when partly decomposed, display a lamellar structure.

The crystalline or columnar form has been considered to be due to the compression of these concretions, and this conclusion has been arrived at as a deduction from an experiment by Mr. Gregory Watt, and described in the "Philosophical Transactions," of 1804, p. 279.

The experiment consisted in fusing seven hundredweight of Rowley ragstone (of which a specimen is exhibited) for six hours, and allowing it to cool so slowly that eight days

elapsed before it was removed from the furnace. The mass was wedge-shaped, 4½ feet long, 2½ feet wide, 1½ feet at one end and 4 inches at the other. Where the mass was thinnest and the cooling most rapid, the texture was vitreous or glassy; where it was thickest and the cooling slowest, it was stony; while the intermediate parts exhibited a transition state. Numerous spheroids had been formed; where two came in contact they were compressed, and when several met they formed prisms. It may freely be admitted that this experiment may give a clue to such phenomena as we find displayed at the Giant's Causeway, Staffa, and elsewhere, but that it accounts for them is probably too much to be granted. We can hardly conceive, since the same column is uniform, or thereabouts, throughout its length, but different in dimensions from its neighbour, which is also uniform, that such a regular arrangement of spheroids of unequal size should take place, as that those of the same dimensions should have been so placed that their axes should be in one continuous line, which would be absolutely essential to produce the result which we see.

I do not think it necessary to deduce from the experiment that the spheroids were formed first and then compressed into prisms; it is more probable, I think, that the prisms of the experiment were the result of the slower cooling of that portion of the fused basalt; and that in the case of the natural columns, it is equally probable that if the cooling had been still slower, there would not have been any concave and convex joints at all.

By an examination of a portion of the cliff where the columns are not regular, and where they pass *upwards* into amorphous whin, we observe a gradual passage from the columnar to the amorphous form, and it is, to say the least, highly probable that if these rude columns were pursued downwards, they would be found to become more and more perfect in their shape.

There may have been crystallization in the ordinary sense, but who shall say?

The basalt of the columns is of a dark grey colour, of very fine texture, and great hardness, being in this respect nearly as hard as that from Gunnerton, and somewhat harder than that from Dudley (Rowley rag).

East from the Giant's Causeway, the basalt rests upon coal measures.

Further to the east, the strata belonging to the coal formation are no longer visible in the face of the precipice, the base of which is entirely covered by huge fragments of rudely columnar trap, which have fallen from the cliff of Fair Head, of which the summit is 535 feet above the level of the sea, and of this height the upper 300 feet consist of columnar basalt.

The columnar basalt of Fair Head, and the coal strata which lie below it, extend eastward as far as the Grey Man's Path—a deep incision formed in the face of the precipice by the disintegration of a whin dike, which in this place traverses both the greenstone and the coal strata.

The strata visible in the face of the cliff, about 300 yards to the south-east of the Grey Man's Path, commencing from the top, consist of

	Feet.	Inches.
Highly crystalline columnar greenstone, columns frequently 20 feet square, about	200	0
Black shale, about	50	0
Non-flaming carbonaceous coal	2	6
Black shale, highly indurated, passing into flint slate	3	0
Second range of basaltic columns, composed of highly crystalline greenstone, the crystals of hornblende smaller than in the upper range; the columns vary from two to three feet in diameter	50	0

Fig 1.

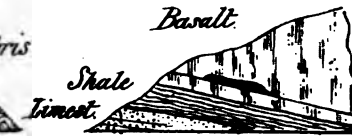
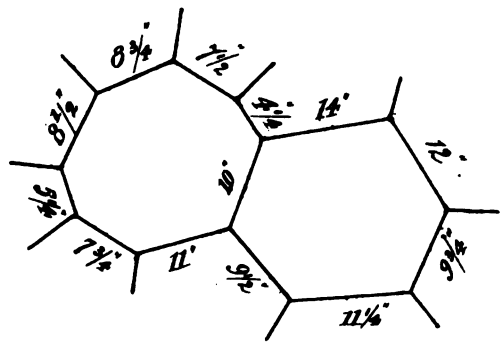


Fig 2.



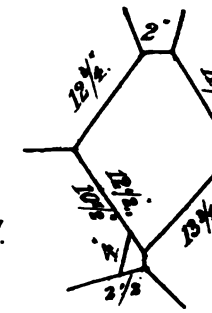


Fig. 5.

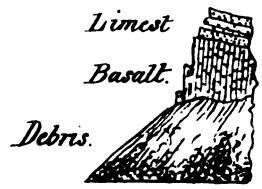


Fig. 3.

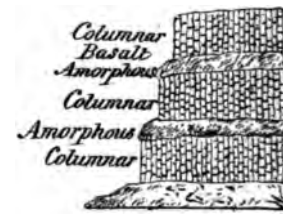


Fig. 4.

SKETCHES TO ILLUSTRATE Mr GREENWELL'S PAPER ON BAS

	Feet.	Inches.
Indurated black and grey shale	4	0
Third range of basaltic columns, highly crystalline greenstone, very fine grained, columns imperfect, about 6 inches in diameter.....	3	0
Indurated black shale, with thin layers of non-flaming coal between the lower layers.....	8	0
Impure non-flaming coal, containing bands of black shale.....	5	0
Black shale	10	0
Yellowish grey shale.....	30	0
Black shale	20	0
	385	6

In a coloured section of the strata of the cliffs in Murlough Bay,* given in the above Survey, we find that the upper bed of basalt lies upon the coal strata unconformably, while the second bed appears to be conformable with the coal strata between which it has been interposed.

Considering the area which has been embraced in this paper, and the great identification which appears to have existed between the results produced in the various districts, it is probably not illogical to conclude that at one period an enormous volcanic action was taking place. This action in the districts referred to must have extended over an area of many thousand square miles.

A vote of thanks to Mr. Greenwell for his paper was unanimously passed.

It was resolved that discussion upon the paper should be postponed until the next ordinary meeting.

* Griffiths: "Geological and Mining Surveys of Tyrone and Antrim," 1829.

Specimens Exhibited.

A collection of fossils, (carboniferous limestone), which had been taken from hæmatite beds, near Furness; exhibited by Mr. Aitken.

A collection of basalts, traps, and other igneous rocks, to illustrate his paper, exhibited by Mr. Greenwell.

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART X. VOL. XIII. SESSION 1874-5.

At the ORDINARY MEETING of the Society, held on Tuesday, 23rd March, 1875.

The President, (Professor BOYD DAWKINS), being absent, Mr. DICKINSON, F.G.S., was requested to take the Chair.

The minutes of the previous meeting having been approved, Mr. A. H. Diggle, Hindley Green Colliery, West Leigh; and Mr. W. S. Barrett, Norley Coal and Cannel Company, were elected Ordinary Members of the Society.

THE LATE MR. T. T. WILKINSON AND MR. T. E. FORSTER.

The CHAIRMAN said: Death has of late been rather busy amongst the Members of this Society. In addition to the distinguished names of Sir C. Lyell, and others, brought before your notice a little while ago, I have now to mention two, namely—those of Mr. T. T. Wilkinson and Mr. Thos. Emerson Forster. Mr. Wilkinson, it seems, was recently re-elected an Ordinary Member of this Society. He was for many years, second master of the Burnley Grammar School, and was held in high esteem for his varied attainments, especially in Astronomy and Mathematics; but he was best known by his valued contributions to the knowledge of the antiquities, and folk-lore of Lancashire. He studied the geology about Burnley—upon which he has written several papers. Mr. Forster was a gentleman well-known to, I think

every mining engineer in this kingdom. He was, perhaps, one of the most brilliant examples that the rising men in the mining profession had before them. As a thoroughly practical man, relying almost solely upon his own application, he raised himself up, from an ordinary sphere certainly to the top of the tree, amongst colliery managers, and, he believed, not only conferred inestimable benefit on the practical part of mining, but also realized a considerable fortune to himself in doing so.

The Discussion upon Mr. Greenwell's paper on "Basalt," read at the previous meeting, was then opened by

Mr. Plant, who said: It is unfortunate that Mr. Greenwell is not here to take part in this discussion. The subject is one which presents many points for discussion, although Mr. Greenwell, in his paper, has not offered any controversial views about the origin of basalt, or any opinion, which can be controverted. So far, the paper is an excellent contribution to the features which distinguish those localities which Mr. Greenwell has himself observed, but there is, at the present moment, in the geological world, a discussion going on with reference to the prismatic character attaching to many of these basalts. Mr. Robert Mallett has very recently, read an elaborate paper upon this subject, and although the views which he advances are not new, he has laid it down as sufficient to explain the phenomena of these prismatic columns that they have been primarily formed by the contraction of the basalt in the course of cooling from a highly heated state.

I believe that all the salient phenomena of prismatic basalt, as observed in a large number of basaltic districts, can be accounted for as results of contraction by cooling in a homogeneous body, not only basalt, but in starch, in common clay, lime, and china clay. If a mass of these

materials, solidified on the surface, but still in a state of great heat within, loses its heat gradually, so that the interior also gradually solidifies, it will in the course of cooling contract, and the contraction of a body not extensible, involves splitting up in some direction or other, no doubt in the line of least resistance, or that line in which there is the least amount of splitting or cracking to do; this has been conclusively shown by many experiments to be at a minimum when it takes an hexagonal form, just as it has been shown in the hexagonal form of the cells of bees, most space is obtained with least wax, so in basalt, &c., hexagons give the most contraction with the least amount of cracking.

Probably, Mr. Gregory Watts initial experiments in 1804, have not sustained their original value to the present time, and are not applicable under modern research into the origin of columnar basalt. But yet it does not upset the fact that there are many instances known in nature, where concretionary spheroid or "onion stones" have resulted from the cooling of volcanic lavas. In the small specimen which I exhibit it will be seen that there are about a dozen prismatic columns formed in a piece of sandstone which had been subjected to the heat of a furnace for some time, and then allowed to cool gradually. It simulates the appearance of the columnar basalt of the Giant's Causeway, and Staffa, and is a good illustration of the result of cooling in a homogeneous substance like sandstone; but it is not uncommon to find this hexagonal structure in nodules of ironstone, hydraulic limestone and clays, which have been made into polygons by a cool process of vaporation of their moisture. I do not think it requires a heated condition at all to effect the appearance of a jointed prismatic structure in mineral substances.

In 1863, I read a paper to the Society, "On the effects produced on Rowley Rag by heat." As this is one of the

basalts mentioned by Mr. Greenwell in his paper, I have brought a few specimens, which exhibit the extraordinary difference in the results, from rapid and from slow cooling, in Rowley Rag basalt when melted, in slow cooling it is almost unchanged from its original state, whilst in rapid cooling it is converted into a jet black obsidian, and can be moulded, rolled, and cast into any form.

Mr. Aitken said: I quite agree with Mr. Plant's observation that Mr. Greenwell does not, in his paper, enter into any question likely to create very extended discussion, for no definite theories are advanced as to the way in which basaltic prisms have been formed, nor does the writer attempt to deal with the question in a very general manner. He has embodied in his paper a considerable number of very interesting facts, which bring the position and character of the various outbursts of trap rock before us in a connected and systematic form. I should have been glad if Mr. Greenwell had gone a little further into the question of the causes—or the forces—that have been at work in producing these various characters of basaltic matter which we find in various places. Previous to hearing Mr. Plant's remarks upon this subject, I had from my own observation, and from a paper which I heard read at the British Association in Belfast, last autumn, come to the conclusion that the prismatic columns of the Giant's Causeway and elsewhere, arose from the mechanical conditions of heating and cooling, expansion and contraction. If we attribute their formation to the mode suggested by the observations upon this subject by Mr. Gregory Watt to spheroids in a molten, on semi-molten state, which by compression in the cooling process became hexagons or polygons, I think, if we follow out the idea there thrown out, so many difficulties will present themselves that we shall find our-

selves compelled to abandon that as a theory meeting all the requirements of the varying characters which we find these columns to assume. It is impossible, I think, to assume, provided these spheroids were formed in the course of cooling, that they should assume an axis directly in a line with each other, and that they should be all of equal size so as to produce columns 60, 80, and even 100 feet in length, with no interruption to their regularity beyond that of their partially laminated character, as represented by the joints which occur at various intervals. Now, if we examine the basaltic outbursts (of which there are undoubtedly three) at the Giant's Causeway, one overlying another, and these resting upon matter composed of red, irony compounds, which are said to represent land surfaces, and which are presumed to show long periods of rest—if we examine these we shall find that they are columnar at the bottom, and towards the top they become amorphous, or broken up, and lose their regularity of structure. It seems to me that this peculiar character can be accounted for on the assumption that this material assumes different forms in cooling with different degrees of rapidity. The lower parts of the structures, as a rule, form prisms in a more perfect degree and order than those near the top, where they would naturally cool most rapidly; and as one passes gradually into the other, we are led to infer—and I think reasonably—that this is, somehow or other, connected with the mode in which the matter has cooled. Hence I have come, on independent grounds, to the same conclusion as that arrived at by Mr. Plant, and which he has so well illustrated, by the facts which he has laid before the meeting. I have often been struck by the fact that if you take a piece of carboniferous shale—fine, laminated shale, with which members must be familiar—from its parent rock, and subject it to the sun in summer, after a few days' exposure

you will find the whole surface reticulated very much in the way illustrated by some of the specimens on the table, these in some cases produce beautiful hexagonal, or polygonal forms, and that is done purely and solely by the action of the sun's rays, the heat and contraction producing fractures in a precisely similar way to that mentioned by Mr. Plant as occurring in clay, in concretionary nodules, and in the red sandstone which has been exposed to heat and afterwards allowed to cool. In this specimen (sandstone from the lining of a furnace) it is evident one portion has become much more columnar in form—more prismatic—than another; and the reason is, that one portion of it has been exposed very much more to the heat than the other portion. It has consequently assumed this particular form in consequence of the unequal heat and rate of cooling to which it has been subjected: you find the prismatic character does not pass through the entire body of the material; and that, I conclude, is one of the best illustrations that could be presented of the way in which it is probable prismatic basaltic columns have been formed. Mr. Greenwell mentions the occurrence of ironstone: I should like had he been here, to have asked him whether this occurs in veins or interlaminated with the basalt. Almost all the basalts with which I am acquainted contain layers of iron; it is generally interlaminated; but Mr. Greenwell, whether intentionally or not, refers to "veins" of hæmatite occurring at Garlton, in Scotland, dipping at an angle of about 75 degrees. To me it would be an interesting fact if this is an actual vein of hæmatite broken through and inserted into the rock in a line at variance with its stratification. Mr. Greenwell's reference to the dike near Egton Bridge—which he describes as standing up above the ground like an ancient military road traversing the country—reminds me very much of a dike of this

character which I saw in the State of Utah, U.S.A., about three years ago, when passing along the Union Pacific Railway. It occurred near Salt Lake City, and penetrated the rocks in that district, in a vertical position, and its peculiarity consisted in the fact that it formed two parallel lines, or walls, six or eight feet apart, and of equal height, running up the steep hillside, as far as the eye could reach, leaving a hollow space between the two, so that a person might—if the side of the hill were not too steep—walk up with perfect safety, and concealed from observation on either side. It is the most extraordinary formation of a dike that I had ever seen, or heard described. It is named the Devil's Slide. The Guides sold on the Union Pacific Railway give a figure of it, and it is one of the objects pointed out to travellers in passing down the magnificent gorge of the Echo Canon.

The CHAIRMAN: I see by the line the discussion has taken that you seem inclined to consider that the whole of these forms are due to contractions in cooling, and perhaps one explanation is as good as another in the absence of proof; but we find that each mineral has its own particular form which it takes in crystallising; and it is only fair to assume that this trap rock, like every other matter that we meet with in the earth, has its particular form also. They are rude crystals, but all on one and the same principle; but as to the circumstances under which they have taken that form we have not yet, perhaps, sufficient data to decide. I was rather surprised to hear Mr. Aitken say that he had met with columns 60, 80, or 100 feet in length, without break, in the North of Ireland.

Mr. AITKEN: I said without interruption to the regularity of the column; but there were breaks across the columns. I did not mean one entire stone of the length named.

The CHAIRMAN: I noticed the word "break" as being rather surprising, because I do not know of any column so long as that. I think, perhaps 63 feet is the highest bed of stratified whin there that I know of. The longest column of the Giant's Causeway certainly does not approach any one of the numbers named. Then, as to the "veins" of iron ore that Mr. Greenwell alluded to: I have no doubt that he meant veins, or lodes, in contradistinction to any stratified bed, because I know this of my own knowledge, that the veins of Cumberland do run down through the whin sill the same as through any other strata.

If any theory is to be built upon that, I think it must be considered as wholly untenable. It requires a pretty good knowledge of geography, as well as geology, to follow Mr. Greenwell in the elaborate description which he gives in his paper on Basalt. Collecting his views together, he appears to consider that the whin or basalt has been injected from below into the dikes, and that the floating or partially stratified whin, called whin sills, are overflows, the component parts of both the dikes and sills being sometimes composed of rounded concretions and the sills sometimes columnar; but he carefully guards himself against assuming definitely that all the overlying masses of whin—naming some in Northumberland—have been formed in the same manner as the whin sill. The crystalline structure he also notices as being more earthy in some basalts than others, and these, he thinks, may perhaps not be of igneous origin; but he gives an analysis of the Staffa basalt, showing no carbonic acid, unless it be included with the 6 per cent. of moisture and volatile matter; and, on the whole, he evidently inclines to the conclusion of an igneous origin and identity with lava. It is, so far as I am aware, a fact, that where whin dikes do not exist there are no whin sills. The absence of whin dikes in the Lancashire

coal field, which Mr. Greenwell names, is an example of this; and the South Wales, Forest of Dean, and other coal fields might be added. No mention is made in the paper of chimneys, such as may be seen on some geological sections, but which, except so far as whin dikes may be so termed, are apparently only imaginary. The description also of the altered effect which is to be seen in rocks near to basalt, I also accept as correct, without comment. It is in the admission that all overlying masses of whin may not have been formed in the same manner as the whin sill, and the doubt as to the igneous origin of the former that the theory of formation of the latter by igneous origin is most vulnerable. The analysis given may, or may not, be strictly correct. I have tested basalt from beds of floating whin, and I find that in at least some of them carbonic acid is present, and I have inferred from that it would be in union with the lime as an impure carbonate and with the iron as an impure proto-carbonate, and I have never been able to reconcile such a state of things with the idea of such rock having been in a molten state. Its melting into a black glass and losing all the previous crystalline structure when exposed to a strong heat is also difficult, if not impossible, to reconcile with an igneous origin. The melting of the mass of Rowley ragstone and the different effects observed on cooling, and another observation, that columnar structure when so formed is at right angles to the direction in which the mass has been cooled, may explain a portion of what is wanted to be known, but not all. I have assayed the whin sill in the crucible with a little charcoal as a re-agent, and I find it easy to run the iron into a button and the other constituent parts into a covering glass. There is also often a difference to be readily seen between the crystalline structure of the whin from a dike and that from a sill, that from the dike being generally finer grained and harder than that of the

bed, and making much better road metal than that of the bed. The stratification which sometimes accompanies some of the beds of whin is also remarkable. In the North of Ireland, the bed of iron ore which is now being extensively worked has whin for the roof and inferior iron ore underneath, and below that a bed of variegated earth, called Lithomarge, which is occasionally worked and used as a flux. There is also a stratified bed of lignite. But neither in the iron ore or the lignite mines, nor at the outcrops, is there any appearance whatever that I have seen of any fluxing such as is produced either in the crucible, furnace, or volcano. In the midst of the cliff of the amphitheatre around, the Giant's Causeway, which Mr. Greenwell describes as passing upwards from columnar to amorphous whin, the bed of lignite forms part of the Cliff. Some time ago I visited the trial there in the lignite, which I climbed up to with a guide, and I made a sketch of it, of which this is a copy :—

Basalt.
Brownish red thin bed.
Lignite, 0 to 6 feet.
Rugged basalt, with balls of agate.
Red ground and iron ore.
Thin bed of red ochre.

On the same day, near the iron ore drift at Portfad, about 2½ miles east of the Giant's Causeway, I sketched the Cliff at Plaskinhead, taking the thickness, which appeared to be correct, from what the guide named :—

Basalt, 60 feet.
Brown earth.
Rugged basalt, with agate nodules, 60 feet.
Columnar basalt, 45 feet.
Red iron ore and red ground, about 40 feet.

Basalt	212 feet.
Brown and red earth	
Basalt	
White and red earth	
Basalt	
White earth	
Basalt	
.. ..	
Basalt	
Red and white earth	
Basalt	
Red ochre	
Basalt	

Level of the Sea.

Where the basalt rests upon the chalk limestone the same peculiar indents are to be seen, such as the gravel makes into the chalk in England. This I consider a very noticeable feature, and not more referable in one instance than in the other to volcanic action. To what then, if not volcanic, are we to attribute the altered character of the rocks when near to the whin? Here I think further data is required before reliable conclusions can be arrived at. Mr. Greenwell well describes the rounded structure like rolled stones and pebbles, as well as columns, which the whin both in dikes and sills assumes; and a discussion which I read a few days ago in the abstracts of the "Proceedings of the Geological "Society of London" may help in arriving at the cause. Mr. Koch said, "he thought steam, charged with fluoric "acid, had played a great part in the formation and "alteration of dikes and veins. He had found that granite "could be deprived of its mica and felspar by this re-agent, "and that its quartz crystals became rounded, just as "in the elvans. The Cornish elvans, and the minerals "associated with them, all contained traces of fluorine. He

"had found that a very small percentage of fluorine could "effect great alteration in crystalline rocks, giving rise to a "peculiar structure and the formation of a certain class of "minerals—*e.g.*, tourmaline, fluor spar, lepidolite, &c.; in "short, the usual minerals accompanying elvans and tin "lodes." Adding these to some of the views which I offered in discussion on Mr. Kendall's paper on the Formation of Hematite Deposits, at our meeting last month, we have apparently the bases upon which to account for the formation of basalts and also of the conglomerates. The whin sills of Scotland, the North of England, Derbyshire, Staffordshire, and the North of Ireland, have a distinctive character. With our present knowledge, I do not think we can safely pronounce whether these rocks have been altered by voltaic and chemical changes communicated by the dikes with which they appear to be connected to the primitive rocks which form the skeleton on which the stratified beds rest, or whether they are overflows which have come up the dikes. A very large portion, however, of the basalts in the North of Ireland is not analogous to the whin sill, but are, so far as my observations have extended, merely altered strata corresponding with the lias, and overlying formations in England.

Mr. Plant: I have no desire to prolong the discussion, but I must take exception to the observation, with regard to the character you ascribe to basalt, as being that which belongs to its nature—meaning that every class of rock has some unchanging character by which it can always be recognised. I think the knowledge we possess of the structure of rocks is, so far as basalt is concerned, quite against such an opinion, basalt assumes, perhaps, as great a variety of colour, of crystallisation, and of form, as it is possible to conceive of any rock in existence, and these prismatic columns are simply the result of peculiar circum-

stances in one part of the cooling of the mass of heated eruptive matter. That the hexagonal form does not belong to basalt alone, is proved by the specimens I have put upon the table. The specimen of sandstone shows that prismatic columns can be produced by heating sandstone. The sample of starch also shows it clearly, and I have mentioned instances where clays, limes, and hydraulic cements all display themselves in prismatic columns when the circumstances are favourable.

The CHAIRMAN: I did not mean it to be inferred that every rock has a distinct crystallisation. I was speaking generally. The laws of crystallography are such as enable us to identify many rocks simply by the crystals.

Mr. C. HARDWICK: I have some specimens of a rock which has been called graphic granite by its discoverers. It was met with in some mining operations, at Glyn Ceiriog, in the upper Silurian formation. There is an abundance of good massive felspar in the locality, but I am not aware that any rock of this kind had previously been observed there. I do not think it properly described by calling it a granite. It appeared more like a hornblendic trap.

Mr. AITKEN said he saw nothing like granite in any of the specimens on the table; they were all felspars and hornblendic trap rocks.

Mr. PLANT: The specimens before the meeting have but little claim to be called granite in any sense; they are undoubtedly greenstones or hornblendic traps. One of the specimens reminds me of a greenstone which is worked at Bowdon, on Charnwood Forest, and the whole appear very similar to the dark greenish traps, so common in North Wales, composed of blackish hornblende and greenish felspar, in small, indistinct crystals, the whole finely veined with calc spar, it may be a new locality for this greenstone, but the rock is very well known.

Mr. J. PLANT read the following paper:—

ON THE ORIGIN OF SOME ARENACEOUS NODULES IN COAL-MEASURE SANDSTONES.

At the June meeting of the Society, last year, in the course of a paper which I read "On Quartzite Boulders "found embedded in Coal," which I endeavoured to show were probably of glacial origin,* I alluded, amongst others, to nodules which were of frequent occurrence in the sandstones of the Coal Measures, which resemble hardened balls lying within the hard sandstone. These nodules are of moderate size, running from a walnut to a cricket ball, and in nearly every specimen I have seen, appear obliquely, but slightly crushed from a spheroid form, externally marked with rings of slightly raised ridges, as though they were roughly turned in a lathe, these external ridges have no relation to the internal structure of the nodules, and do not, I believe, belong to the lines showing the sedimentary layers in the sandstone beds. These nodules occur most frequently in the fine, hard sandstones, such as are used

* At the time of reading my paper "On the Quartzite Boulders," I was quite ignorant of the existence of a paper by Mr. Binney, which is printed in the Memoirs of the Literary and Philosophical Society of Manchester, Vol. IX., second series, 1851, "A Description of some supposed Meteorites found in Seams of Coal," in which are figured several of these quartzite boulders, and the paper gives an interesting account of their mode of occurrence in the coal, their origin being considered by the author as meteoric during the carboniferous times. This supposition of their origin would be altogether at variance with the present exact knowledge of the composition of meteoric stones, of which no instance is known of a pure crystalline quartz, or compact quartzite, such as these boulders consist of, to be exhibited by true meteorites; besides which, these quartzite boulders have not the slightest trace of igneous action, externally or internally. My claim for their origin is a glacial one, as described in my paper.

for buildings and stair-landings, and when the stone is worked to a fine surface, the sections of the nodules are seen as brownish markings of faint concentric rings. In working the stone the nodule frequently becomes loosened, and fall out as cleanly as do the quartz pebbles from the pebble beds of the new red sandstone. These nodules rarely differ in texture from the sandstone matrix, of which they are really formed. The only difference lies in their colour, which is often a deep brownish red, and contrasts forcibly with the lighter colour of these building stones. When a section of a nodule is carefully ground, it exhibits a series of light and dark rings encircling a central nucleus, and the nucleus shapes are in most specimens rather indistinct, when contrasted with the regular rings. The rings have not the remotest appearance of a coated growth, such as is so common in oblong nodular ironstones and clay—ironstones from the Coal Measure shales,—and it is not possible to break one of these globular nodules along the periphery of a ring, and they never weather in such a way as to show that their formation was originally due to the accumulation of a succession of layers cementing around a central nucleus, it is rarely that any organic fragments are found within these nodules, when it is so, the leaf of fragment of plant stem never forms the central nucleus. The nodules externally, might suggest an origin like that of a ball of sand cemented by the oxide of iron, but the external ridges are difficult to account for by any kind of rolling motion, and even were it to be regarded as a nodule produced by motion, the internal structure will never be reconciled by this mode of origin.

After careful examination of a large number of these nodules, I have concluded to regard them as the results of the slow decomposition or oxidation of stray particles of iron which originally existed in the sandstone, and which being slowly oxidated, was diffused in the sandstone, in a series of

gradually enlarging circles, until the amount of oxidation was used up. The whole circle or ball is saturated with peroxide of iron, but the process of saturation was not uniform and hence the appearance which the nodules exhibit of a succession of iron-stained rings, the last formed circle has by its oxide effected the hardness of surface which enables the nodule so readily to separate itself from the sandstone. I have experimented in several ways to realize a similar nodule in clay, lime, or sand, but the result has been unsatisfactory inasmuch as the oxidation of the iron requires more time than I have given to it to radiate in circles from a central nucleus, some experiments upon damped paper have been more successful, and in those which I now exhibit it will be seen that a particle of iron when placed upon damp paper, and under a slight pressure has in eight days resulted in the production of a series of iron-stained rings which present a *fac-simile* of the iron-stained concentric rings seen in the sections of these nodules, and I submit that that is a view which probably correctly explains the origin of these particular nodules which are found in these coal measure sandstones of Lancashire.

The thanks of the meeting were given to Mr. Plant for his paper.

The CHAIRMAN said: Many years ago the subject of the concretions which are found chiefly in the Roger mine, in the neighbourhood of Dukinfield, (one or two had been found in the Blackmine at Barnsley, and others in the Trencherbone mine, on the western side of Manchester,) was brought before the Society; and Mr. Binney, in a paper which he read, said he considered them to be meteoric stones. I ridiculed the idea, and at a subsequent meeting, brought

a sack full into the room, upon which he said, I think the idea of their being meteorites must be given up now. They seem to be aggregations, or concretions in the sandstone, and take a particular form perhaps owing to the quantity of Silica which is present.

Mr. PLANT: I have not seen any report of the meeting to which Mr. Dickinson had alluded, perhaps, because it did not appear in the Transactions of the Society, and he was necessarily unaware of the change which had been effected in Mr. Binney's opinions as to the origin of the quartzite boulders in the coal—but the arenaceous nodules which were now before the meeting, had no relation to the boulders.

Mr. Plant exhibited a fossil, undoubtedly representing what is figured by the American geologists as a species of algæ—*Arthrophycus.** It was the only specimen that he had seen, and was worthy of being recorded in the palæontology of Lancashire; it was found in the Upper Silurian flags in Cartmell.

Mr. AITKEN: I am very much obliged to Mr. Plant for bringing this specimen for exhibition. I saw it on coming into the room to day for the first time; but if I had discovered that specimen, I should have put it down as having had an animal origin and not the remains of a vegetable, it is rather difficult to conceive of a plant whose principal constituent would be water—growing on the sea shore—retaining the large body which is represented upon the surface of this stone. It is nearly square—a very unusual form for a vegetable stem to assume; but as my acquaintance with the specimen is so recent I cannot give a positive opinion. Its vegetable nature is, however, in my judgment, open to doubt.

* Hall. Pal. New York, Vol. II., pl. 1-2, pp. 5-6.

Mr. PLANT: The appearance of the fossil on this piece of sandstone is quite abnormal, no doubt, originally, the stem was round, as most stems of sea weeds are. I believe that it is only a cast of the algæ stem, and we should not judge too closely of what may have been its original or normal condition.

The CHAIRMAN: I have seen similar appearances in the coal formation to that at the end of the stem; and if this specimen is from the mountain limestone, there is no reason why the same form should not be extended a little lower down into the carboniferous series.

SPECIMENS EXHIBITED

By Mr. PLANT, a series of prismatic columns in sandstone, clay, lias, starch, &c.

Mr. HARDWICK, a series of rocks, hornblendic, and felspathic, from North Wales.

At the ORDINARY MEETING of the Society held on Tuesday, 27th April, 1875.

Professor W. BOYD DAWKINS, F.R.S., President, in the Chair.

Mr. DANIEL MORRIS, F.G.S., the Grammar School, Burnley, was elected an Ordinary Member of the Society.

Mr. A. W. WATERS, exhibited specimens of a Belemnite *(B. rugifer)*, from the Bartonian nummuline limestone at Ronco, North Italy. He said these deposits were regarded by the Italian geologists as belonging to the Eocene age.

This Belemnite differed in some important points from the ordinary Liassic forms, but, it was open to question whether the fossil was really living in Eocene times, or whether it had been transported as a fossil by aqueous agency from some older bed, although there were no Liassic beds in the immediate neighbourhood of Ronco, they were to be found about twenty or thirty miles distant.

The PRESIDENT: It has been hitherto the custom with palæontologists to consider Belemnites as belonging to the Mesozoic age in Europe, howsoever they had been derived. These specimens were probably washed out of older rocks, and deposited in the Eocene sea bottom, like the fossils from the London clay in the Crag of Norfolk. He had the pleasure of examining the magnificent series which the late Professor Phillips collected for the purpose of his monograph, and the forms now exhibited corresponded more closely with an Upper Lias form, than any other.

Mr. PLANT: If I am not mistaken the range of the true belemnite is limited between the Lias and Gault, and I believe that Professor Phillips in his introduction to his monograph on the Belemnitidæ, says, "not only is the "group absent from existing oceans, but it is unknown in the "whole Cainozoic period, for probably Beloptera and "Belemnosis which occur in Eocene strata are of the family "Sepiadæ." These latter fossils are found in the London clay at Bracklesham, and in the Paris basin, and might be mistaken for parts of a belemnite, no such mistake could be made with the specimens from Ronco, they are undoubtedly true belemnites, it appears to me that the points to be decided are, whether the beds in which they were found be Eocene, or whether the fossils have not been derived from older beds and redeposited in Eocene times, an instance of this redeposition is to be found in the Keuper sandstone at Mottram St. Andrews, near Alderley, where specimens of

"*Syringopora ramulosa*," a common carboniferous limestone coralline, are not unfrequently found embedded in the later Keuper beds.

Mr. AITKEN said: It was an interesting subject to consider. He thought the fossils had the aspect of Liassic belemnites.

ON LEAD MINING IN THE DISTRICTS OF STANSFIELD, HOLMES CHAPEL, ROSSENDALE, AND GREAT HAMBLEDON, N. W. YORKSHIRE, AND N. E. LANCASHIRE.

BY MR. JAMES KERR.

On casting the eye over a Geological map of these districts, one cannot but be struck with the vast number of faults they present, and their diverse directions.

Both Professor Hull* and E. C. DeRance† have referred to a part of the district under consideration, and as the latter quotes the former, and gives a good account of it, I shall with your permission give his remarks, in so far as they are connected with the subject of the present paper. After speaking of several other localities, he says in reference to this: "At Thieveley, four miles S.S.E. of Burnley, there are E. and W. faults with a northerly downthrow of 340 yards, throwing the rough rock of the millstone grit and the bottom beds of the lower coal measures against higher beds of the latter, and the basement bed of the middle coal measures, on the breast of a

* Professor Hull, M.A., F.R.S., F.G.S., Director of the Geological Survey, Ireland: "Lines of Elevation &c. of Carboniferous, districts of Lancashire and Yorkshire," *Quart. Jour. Geo. Soc.*, vol. xxiv., 1868, pp. 328-331.

† E. C. DeRance, Esq., F.G.S., of the Geological Survey, England: "On Lead, Zinc, and Iron Ores in the N.W. of England," *Geo. Mag.*, Feb., 1873, vol. x., pp. 66-67.

hill called Deerplay Moor, nearly 1500 feet in height, the beds dipping into the hill at low angles. Here the slope of the hill and fault is to the north, the lode ranging half way across the hill, sloping down towards the Calder." Having previously quoted Mr. W. Wallace's "Laws governing the distribution of lead," he proceeds to say, having reference to those laws: "The distance from the watershed is not great, nor are the other conditions very favourable, but as the works are now discontinued, the quantity of lead in the lode is probably not very great. But it is remarkable as being the highest lead-bearing horizon in the carboniferous rocks of the district, with the exception of the lead mine fault to the west at Hambledon Hill, about two miles east of Accrington, where the Arley Mine, the lowest coal of the middle coal measures, is often permeated with strings of galena; and much lead occurs in the centre of the fault, which traverses the top of the hill at an elevation of 1330 feet, throwing the strata, which dip at a small angle to the south, 80 yards in the same direction. The hill has a steep escarpment to the north, and is more or less isolated on either side, proving considerable denudation of rocks since the infilling of the fault with lode stuff and other matter, for the fault and beds dipping from the escarpment give no gathering ground for water to pass through and collect ore. In a paper "On the Relative Age of the Lines of elevation of the carboniferous district of Lancashire and Yorkshire," Professor Hull has shown that the great series of E.N.E. anticlinal and synclinal folds exhibited in the hills of Millstone and Yoredale Grits of the "Pendle Range," had taken place, and great denudation gone on, before the deposition of the Permian strata upon their upturned and denuded curves, and that a second system of disturbance (the Pennine,) ranging nearly north and south, uplifted the Pennine chain, and dissevered the Lancashire and York-

shire coal-fields, at the close of the Permian era, which was followed long after, probably after the deposition of the Oolites, by a third system of lines of fracture ranging N.N.W.

From the researches of Mr. J. M. Wilson, M.A., it appears probable, and even certain, that contortions are the inevitable results of subsidence of a curved surface, and that faults are cracks the result of the re-elevation of that curved surface, in which "the rocks have to expand, so as to fill a larger area." From which it would appear to follow that the curves of the Pendle range were the result of a subsidence taking place at the close of the carboniferous era, accompanied by much marine denudation, produced by a sea, which on re-elevation became inland and land locked."

The lead mining operations about to be described are connected chiefly with the faults of the Pendle range, in several of them, besides the fault referred to by Mr. DeRance, is deposited a portion of lead ore, in the form of galena, associated with less or more of sulphate of barium,* and a limited quantity of sulphide of zinc, in the form of blend. In the quotation given above, it will be observed that Mr. DeRance favours the theory of the introduction of the lead into the faults, from the surface, and in other parts of his paper he speaks even still more decidedly on its behalf. As this however, is a disputed point, I prefer waiting till it is more thoroughly discussed, before expressing any opinion upon the question as to whether the metallic ores were deposited in the faults from the surface, during the denudation of the higher strata, or were elevated from beneath, either by sublimation, on the one hand, or on the other by the agency of superheated or thermal waters, in which they had been dissolved under pressure, and from

* This mineral was determined to be not sulphide of baryta, but sulphate of barium, by Mr. Davis, British Museum.

which they were subsequently deposited during the process of refrigeration.

In whatever way the lead was deposited in the faults of which we are now speaking, it may be said that, with the exception of occasional sops or pockets, the lode is throughout not only poor, but in consequence of the contorted, dislocated, and cross-jointed condition of the rocks through which it passes, very frequently interrupted.

The position of these lead-bearing faults is best seen on the six-inch maps of the Geological Survey, Nos. 63, 65, 71, 73, Lancashire Series, or on the inch maps, Nos. 88 and 89; but their course is here laid down so as to be traced upon an ordinary map of the district.

Cat Holes Clough begins, as we have said, opposite to Robin Wood Mill, on the north-east side of the Burnley and Todmorden road, and is just within the borders of the north division of West Yorkshire (map No. 229). The lead mine lies in a small branch fault, running nearly north and south, the southerly end beginning at 53° 43′ 88″ N. lat. and 2° 7′ 30″ W. long. It is about 15″ in length, having the 2nd Grit on the east and the 3rd Grit on the west. It thus appears that either the full length of the fault is not laid down, or that the mining was continued beyond, or that the reputed length of the drift, three-quarters of a mile, is an over-estimate.

The "Cliviger Valley Fault" begins on map No. 64, at its southern extremity, viz., 53° 43′ 27½″ N. lat. and 2° 10′ 1½″ W. long., with a downthrow to the north-east, and sweeps through the sheet, at first, in a north-west direction, but afterwards verges a little more towards the north. After running for about half a mile, having the lower and middle coal measures on the north-east, and the 2nd Grit on the south-west, it gives off, at 53° 44′ 40″ N. lat. and 2° 10′ 40½″ W. long.; on the west side, the Thieveley

fault, with which we are at present more immediately concerned. This fault has a downthrow to the north of 340 yards, having the lower coal measures on the north and the 2nd Grit on the south, until it reaches a little to the west of Thieveley farm-house, where it is bounded on both sides by the lower coal measures. Continuing to run west, it passes through Black Clough, and when nearly opposite to Cow Side farm-house, it begins to be bounded on the north and north-east, for over half a mile, by a patch of Arley Mine, the lowest bed of the middle coal measures, the north-west portion forming part of a long fault running from north-west to south-east. On the south and south-west it is bounded by the lower coal measures. It now again strikes off almost directly west, verging now and again a little to the north or the south; while on the north it has another downthrow. At 53° 45′ 5″ N. lat. and 2° 16′ 33″ W. long., while still running in the lower coal measures, it bifurcates into two branches—a north and a south. Soon after passing Bridgeley Bank farm it becomes the north boundary of the Rossendale and Great Hambledon Arley Mine, with, first, an upcast to the north, and subsequently a downthrow to the south. In its course it passes a little to the north of the old Cupola Coal Pit, on Hapton High Park, and then over Great Hambledon Hill, a little to the south of its summit, leaving on its north side an almost semi-circular patch of the Arley coal, at an elevation of 1342 feet above sea level, the highest point in the neighbourhood. With this exception, it has on the north the lower coal measures until it reaches the west extremity of the Arley Mine, at Moleside plantation, whence it has on both sides the lower coal measures, till, at 53° 45′ 24″ N. lat. and 2° 20′ 55″ W. long., it reunites with the south branch.

This south branch has an upcast south, and continues to pass through lower coal measures, till, just within Dunoakshaw Close, it becomes the south boundary of the

Arley Mine, having on its south side the lower coal measures. On leaving the Arley Mine, it passes on through lower coal measures for about half a mile, rising in a north direction, till, at the point already named, it rejoins the north branch. Thus these two branches hem in on the north and south this isolated patch of the Arley coal, the general breadth of which is one-third of a mile, while its length is about two miles. Through this mine there are two faults, passing diagonally in a south-east and north-west direction, the first uniting the bounding faults, and the second passing through about a fourth part of the breadth of the coal. In these branches are found the *strings* of lead ore to which Mr. De Rance refers. What has been stated with regard to the horizon of the main fault, is generally true as to the minor branches, the chief of which are an isolated V shaped fault, running from Hey Head down Green Hill Clough and through the Clow Bridge Reservoir to Nutshaw Hill, and the one passing through Cribden Moor, the former having the lower coal measures on both sides, while the latter has lower coal measures on the north and the 1st Grit on the south.*

At what period lead mining was first attempted in the faults just described, I cannot say, but as "repairing the old shaft" and "driving a sough up to the old vein" formed part of the earliest work done by the company about to be named, and as a portion of an old lead level was found some years ago, which appeared to have been formed anterior to 1753, it seems very probable that this company was not the first in the field. There are also some old works on the brook side, opposite the ruins of Hapton Tower, on the line of fault extending from Porter's Gate to Barley Green, which look very like lead mining operations.

* In accordance with a wish expressed at the time this paper was read notice has been taken of the strata through which the faults pass; the "1*st Grit*," &c., being the Grits as given in the Geological Survey.

The first company which I propose to notice was formed in the middle of last century for the purpose of carrying on mining operations in the "Honor of Clithero." In the books * of the company it is variously described as: "The Clitherow Mining Co.," "The Clitherow Co. of Miners," and lastly, but not least significantly, as "The Mine Adventurers' Co." The office of the company was at Dunoakshaw, one of the "booths" of the ancient forest of Rossendale, on the Burnley and Edenfield road, N.E. Lancashire. The first items in the company's books, dated August 16th, 1753, are the "Expenses of Mr. Percival and Mr. R. Kershaw's journey to view Thieveley, 13s.;" and "two journeys" of the same gentlemen "to Manchester 10s." On 26th February, 1754, 6s. was paid to "Old Charles Lord to view Brown Backs," and in the following April, Thieveley was taken on lease. On the 13th April, Messrs. Percival and Nangreaves, afterwards called Lawyer Nangreaves, go to Castleton and Oakes, in Derbyshire, to engage miners; on the 22nd active operations begin, and on the 29th wages are paid by "George Crompton, clerk," at Dunoakshaw.

Sometime in the course of this year, the mining rights of the Company became very extensive, as appears from an advertisement issued by them, of which the following is a copy: "1754, Notice is hereby given, that the lessees of the lead mines, veins or beds of lead, copper, iron, or tin, lying and being in any of the copyhold lands, wastes, commons, and waste grounds belonging to the wapentake of Blackburnshire and the several manors of Ightenhill, Coln, Chatburn, Worston, Pendleton, Accrington, and Tottington, in the honor of Clithero and county of Lancaster, hereby propose to lett any mear † or mears of ground within

* For a perusal of those books I am indebted to G. Ashworth, Esq., J.P., and H. H. Bolton, Esq., of Newchurch-in-Rossendale.

† A "mear" was "29 yards of the rake vein in succession." The lessor *taking* the next 14½ yards.

the manors or liberty aforesaid, with free liberty to search, sough and drain, dig and delve for the same, to any person or persons, for a term to be agreed upon, not exceeding fifteen years, in some parts of which manors and liberties a large quantity of lead ore has lately been got. For further particulars enquire of Thomas Percival, of Royton, Esq.; Thomas Johnson, of Manchester, Esq.; or John Hargreaves, of Newchurch-in-Rossendale, Gent.; all in the said county of Lancaster, who are empowered to treat for the same."

"Manchester: Printed by Joseph Harrop, opposite the Exchange; where printing in general is neatly and cheaply perform'd."

The various places at which the company opened works, or went in search of ore, were Thieveley, Black Clough, Gambleside, Whin Hill Clough, Dunoakshaw Close, Thornybank Clough, Goodshawhill, Cribden, Risingbridge, Baxenden, Pendle, Pendle Risk, and Worston. There is also mention made of Bolland, Rivington, and Brennand, but the ore from these places seems to have been obtained by purchase.

At many of the above places there are still to be seen traces of lead mining, in the form of old drifts or levels, shafts, dressing hills, and quantities of scattered stones, so impregnated with lead, that vegetation still refuses to cover them. These remains are to be met with at Thornybank Clough, on the old road from Love Clough to Hapton, where there is a drift of two dressing hills. At Whin Hill Clough, which divides the townships of Higher Booths and Dunoakshaw, where there is a drift on the south side, traces of six or seven shafts, and nine or ten mounds of *debris*. At Goodshawhill, near the farm house, on the east side of a footpath running along the Rough Hill pastures, towards Townend Close, there is an old drift, beside which sulphate of barium * lies scattered. Near Cribden House, sometimes

called Far Houses, there are signs of mining in a small clough running along the N.W. skirt of the hill, and on and beside a footpath running eastward from the same place may be seen scattered specimens and a vein of sulphate of barium,* large pieces of which are piled up as rock-work in the adjoining garden.

On Thieveley Farm, at 1078 feet above sea level there are three places at which lead mining has been carried on. At the W.S.W. end of the farm house there are 12 filled up shafts and a large mound of lead-dressing *debris*. Proceeding in a westerly direction we reach a part of the same farm called Black Clough, where there are a dressing hill and six old filled up shafts, on the right bank of the stream, and a little higher up, on the left bank, there are four filled up shafts and another dressing hill. On each of the three dressing hills may be found small specimens of lead ore and sulphate of barium.

At the places just named, the company continued its operations during the greater portion of its existence, while in the course of the first four years of its time the others were either but partially worked or altogether abandoned. Whin Hill, Cribden, and Dunoakshaw Close mines seem to have been the most productive, and at the latter place so extensive was the search for lead, that the farmer was allowed a deduction in rent equal to that of three acres of the land.

Along with the galena, (sulphide of lead), there has been found not only the sulphate of barium, as already mentioned, but also blend,† (sulphide of zinc) which I take to be the "*Calamy*" I find named in the books, as no calamine, (carbonate of zinc) is to be found in the neighbourhood.

* This sulphate of barium is not noted on the maps of either the Geological or the Ordnance Survey, nor is it mentioned as occurring at Black Clough and Thieveley Farms.

† Blend has been found in moderate quantities by several subsequent explorers.

Determined to carry on their speculation with vigour, the company built a smelting furnace, the remains of which I discovered in Cupola Clough, near the upper extremity of Great Clough. This cupola was begun in June, 1755, and finished in the following November, at a cost of £61 7s. 2½d. for the mason work, stone and lime being supplied by the company, and a further expenditure of £3 3s. 4d., apparently for appliances, making a total of £64 10s. 6½d. This seems a small sum for a cupola which had a long chimney attached, but at that time the prices of work and materials were very low, mason work being 8d. per yard, stone getting 4d., and stone leading 2½d., while lime cost 21s. for twenty horse-loads, and carpenters' wages were 1s. 1½d. per day. From the fact that this furnace was built in the bottom of an almost inaccessible cwm, it seems likely that the chimney was built according to custom, as a flue running up the adjoining acclivity, and terminating in a perpendicular stalk, on the more level ground at the top. This supposition is favoured both by the limited cost of the erection, and also by the small quantity of lime employed in its construction. That it was a long chimney, is supported by the tradition that the flames issuing from it were seen at some distance in different directions, which its position would have precluded, had it been short, and also by the tradition, that for a wager a man crept up it, from bottom to top, and died from the effects of the vapours inhaled during his progress.

From the way in which the various items of income are entered in the books, it is difficult to ascertain with exactitude the amount realized by the sale of ore and lead, but taking the most liberal view of the case, and including the parcels obtained by purchase from other mines, it fell short of £1200. Taking the lowest price at which the ore was sold, viz., "12s. * per cwt. of 120 lbs., or two short dishes of

* The greater part of the ore was sold at 13s. per cwt., while the share falling to the Lord of the Manor was valued at £9 per ton.

60 lbs. each," this would give a yield of 100 tons, of their weight, or an average of 12½ tons per annum, during the eight years of the Company's active existence. £82 was obtained for "borage" from parties who availed themselves of the offer made in the advertisement quoted above, and the sum of about £1600 was paid in share money. Thus the amount raised by the company for lead and ore, borage, and share money makes a total of £2882. From this deduct the £29 returned to the shareholders as a first and final dividend, at the rate of 11s. 4d. per share, and we have left £2853, the whole of which was expended in the prosecution of the company's scheme. In other words, for the £1200 they obtained by the sale of their ore and lead, they paid the sum of £2853, equivalent to a dead loss of £1653.

The number of shareholders in the company seems never to have exceeded 13, at any one time, holding among them about 50 shares, which cost in calls some £32 per share. No shareholder held more than 10 shares at the first, and only one man held above that number, viz., 13, at the close, when the number of shareholders was reduced to 10, holding 52 shares in all.

The shareholders, as a body, must have had no inconsiderable amount of faith, hope, and courage, for to their credit it must be said that they gave the scheme a full and a fair trial, and continued the struggle until in the end they were compelled by the logic of facts, to come to the conclusion, that success was impossible. The company was formed in 1753, and finally wound up in 1766, after an active existence of about eight, and a nominal one of thirteen years.

Notwithstanding the disastrous termination of this first company, a second one, consisting partly of the old shareholders was formed in December, 1768, when a first call of 10s. per share was made. In the following year, a second and a third call were made, but in February, 1775, the cash

book closes with "Paid the New Shareholders," what appears to be as in the case of the former company, a first and final dividend of 1s. per share.

In spite of these signal failures lead mining has been attempted, and carried on for a time, by individuals and small companies, about Dunoakshaw, Dunoakshaw Close, and Thornybank Clough, to within the last five or six years if not later, but in every instance it has proved in the end an unprofitable speculation.

On the Burnley and Todmorden Road, about a mile and a half from the latter place stands Robin Wood Mill, and opposite to it is a viaduct, passing through which you enter Cat Holes Clough. About half-a-mile up this Clough, are the Cat Holes Lead Mines,* which were first brought into operation about 120 years ago. On the right bank of the stream is a drift, which runs under the hill for three-quarters of a mile, and on the left, a little higher up, there is another, but much shorter, with neither lead nor sulphate of barium about it. At the mouth of that on the right bank, there is a large quantity of sulphate of barium with a little lead, the sulphate of barium forming the matrix of the ore. Here the lode passes beneath the rough rock, which is very much contorted and cross-jointed. The consequence is that the continuity of the lode is frequently interrupted. Its width is stated to have been from three to eighteen inches, the latter being probably only in limited pockets. Be this as it may, the cost of extracting the ore so far exceeded its value, that the speculation is said to have ruined the parties engaged in it.

About the same time as this mine was opened, viz., 120 years ago, another mining company began operations at Leadmine Clough, Stansfield Moor, but this company was equally unsuccessful and had ultimately to be given up.

* I am placed under obligation to Mr. Abraham Stansfield, of Todmorden, for information respecting these mines.—J. K.

Referring apparently to the disastrous termination of all these companies, Dr. Whittaker, in his history of Whalley, expresses his opinion that next to a cotton mill, the opening of a lead mine, is as great a curse to a district as can befall it.

About forty years since, the Cat Holes mine was re-opened by some Welsh miners, assisted by two gentlemen in the neighbourhood. A few tons of lead ore were obtained, but again at a cost beyond its value. This time, however, attention was turned to the sulphate of barium matrix. This was ground down to an impalpable powder, washed and bleached, and then sold to the Walsall dealers in white lead, to be used as an adulteration. The manufacture of this article was carried on for some time, but this too, proving a losing concern, was also abandoned.

Six years since, the Cat Holes mine was again opened by a limited liability company, which after spending £500 in a two years' search for lead, without obtaining a farthing in return, commenced and continues to pursue the more profitable business of brickmaking.

Having now passed in review the history of the foregoing lead mining operations, the question naturally arises: What was the cause of their uniform and utter failure? The answer is at hand; it was neither reckless expenditure, nor want of persevering effort, but solely want of ore, arising from the general poverty of the lode, aggravated by its want of continuity, owing to the cross-jointing and dislocation of the strata through which it passed.

It seems to me probable that, the loss of the Clithero Company would not have been so great, had the directors concentrated their energies, instead of spreading them over so great an area. In addition, from the quantity of lead still left in the slag, it is evident that the more exhaustive methods of extracting it were not employed, probably because not then known. The company had also to work to some extent in the dark, Geology being then, to

put it mildly, in comparative infancy, and the benefits of the Geological Survey, as a matter of course, totally unknown. In fact, the lode was only worked where denudation had made the presence of ore less or more visible, while by far the greater part of it was left absolutely untouched. The general poverty of the lode, however, renders it probable that, were all the appliances of modern science brought to bear, the working of it would still prove unprofitable.

It now only remains to give, as bearing on the cost of mining, a list of the wages paid, and the prices of articles in 1753—1762. This list is extracted from the books of the Clithero Mining Company.

WAGES.

Manager, 16s. per week. A succeeding manager 21s. per week.

Treasurer, £10 10s. per annum.

Smelters, 12s. per week.

Sinkers, 10s. 6d. per week.

Sinking at Dunoakshaw apparently in drift* 5s., 6s., 7s. 6d. per fathom.

Sinking in rock, "£2 per fathom, finding them candles and powder."

Miners, 1s. 8d. per day.

Sough level driving, 1s. 4d., 1s. 8d. per day.

Washing ore, 6d. per dish of 60 lbs.† Female washers, 7d., 8d., 1s. per day.

Carpenters, 1s. 1d., 1s. 1½d. per day.

Mason work, 8d. per yard.

Stonegetting, 4d. per yard, 1s. per day.

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* The deepest shaft named, is here, viz: Ten fathoms, 50s.

† A *short* dish of ore, contained 14 Winchester pints; a long dish, 16 Winchester pints of water. A dish, as now settled by law, contains 15 pints of water. The original *dish* was a wooden box of about 28 inches long, 6 inches wide, and 4 inches deep. In this the dressed ore was measured when ready for smelting.

Labourers assisting miners, 1s., 1s. 2d. per day.

Ditching, 7d. per rood.

"Richard Whittaker in full for building a house £2 11s. 6d."

PRICES OF VARIOUS ARTICLES, &c.

Coals per load, presumed to be 3½ cwt., including carriage, 4d., 4½d.

Coals, bought in quantity at the pit mouth, 2½d. per load.

Candles, 6d., 6½d. per lb. In quantity a trifle lower.

Powder for blasting, 1s. 2d. per lb.

Lime, "20" (horse) "loads," including carriage, 21s.

Rushes, 6d. per load, laid down. Man and horse leading rushes, 1s. 9d. per day.

Making 12 ore bags, 1s. Cluking (band to make them with), 1d.

Postage of letters, 1d. each. One from Clithero, 4d. Two spade shafts, 4d.

Messenger from Dunoakshaw to Rochdale with a letter, 9d.

The PRESIDENT: We have listened to this paper with unusual interest, as it has not only thrown a light on the speculations in lead mining in past years, but we may also gather instruction as to the condition of lead mining in this country, for the most part, at the present time; and with regard to economical questions, I think it has opened our eyes to the wonderful advance in the price of things which has taken place since the time referred to by Mr. Kerr.

Mr. AITKEN: I do not know that I have anything of interest to say on this question, beyond expressing the thanks which I am sure we all feel to Mr. Kerr for the trouble he has taken in investigating this very interesting subject, and in laying the facts in so presentable a form before this meeting. I am pretty well acquainted with the direction and with the circumstances of this fault for a very considerable portion of its length, which is known as the

lead mine fault, having traced it at points where it is visible on the surface. I am sure we are very thankful to Mr. Kerr for having rescued from oblivion the record of those interesting operations which took place some 120 years ago, not only as showing the position of lead ore in the district, but also the quantity that exists there, and the economical questions connected with the working of these mines in past times.

Mr. PLANT: I may be allowed to ask one or two questions. I was in hopes that Mr. Kerr would have given some explanation of the actual position of the lead ore. I do not remember that I ever saw a specimen taken out of the lower coal measures, therefore it is perfectly new to me, and I should have been very much interested in a description of the horizon where the lead occurs. I see the fault laid down is not the great fault which separates the coal measures from the millstone grit, but a subordinate one, and very likely the speculations which have been so disastrous from the time when they were first commenced—though not so peculiarly disastrous as some speculations at the present day—might possibly be profitable if lead were searched for in a more scientific manner.

The PRESIDENT: With regard to this question of the distribution of lead ores in the coal measure rocks, I believe there are certain isolated places, such as this, in which these ores are to be met with; but, as a general rule, it may be said that the lead ores are never worth working in any open grit-stone rocks, or in any of those shaley and clayey strata such as you meet with in the coal measures. Speaking in general terms of lead mining, one reason why it is so extremely hazardous, and why such large sums of money are annually lost in it in this country, is that for the most part the lead is found in the carboniferous limestone, and the carbonferous limestone has certain beds of shale in it. The lead ore may be tolerably good while it is traversing

TRANSACTIONS

OF THE

MANCHESTER GEOLOGICAL SOCIETY.

PART XI. VOL. XIII. SESSION 1874-5.

At the CONCLUDING MEETING of the Society for the Session, held on Tuesday, 29th June, 1875.

JOHN AITKEN, Esq., V.P., F.G.S., in the Chair.

A letter from the President (Professor DAWKINS) was read, stating that he was on his way to Australia, for the vacation of three or four months, and therefore would be unable to take part in the meetings of the Society.

The SECRETARY announced that the North Staffordshire Naturalists' Field Club had arranged for a geological excursion to examine the picturesque district known as "The Roaches," near Leek. The section to be examined lay chiefly in the third grit of the Millstone Grit Series. The party was to be conducted by Mr. Thomas Wardle, F.G.S., and members of this Society were invited to join the excursion on July 17th.

ERUPTION OF VESUVIUS, 1872.

Mr. W. J. BLACK, F.R.C.S.E., &c., read the following paper, giving a description of the phenomena of the great eruption of Vesuvius of 1872, compiled from the journal of his brother, Mr. J. M. Black, then staying at Naples, and from information collected from descriptions in the journals of the time:—

DESCRIPTION OF THE PHENOMENA OF THE GREAT ERUPTIVE LAVA STREAMS.

The chief phenomena connected with this eruption were the pillar of cloud, the streams of lava, and the showers of ashes that succeed the scene of terrestrial conflagration, and the meteorological convulsions that close the drama of volcanic action.

When this eruption began on Tuesday, April 23rd, there were first observed a set of minor streams that ran down the sides of the cone, chiefly in a north-easterly, southerly, and westerly directions, from the overflowing of the molten lava over the depressions of the crest of the Crater, and the mountain was said to "sweat."

None of these seemed to get further than the base of the cone, and many did not extend so far, and principally caused alarm from the probabilities of what might happen if they got further, and so were said to "threaten." There were, however, only two main ones on this occasion larger and longer than the above, one flowing to the north-west towards Naples, and the other south-west to the sea coast, and each of these branched out and went in other directions, and so gave the appearance of there being a great many streams of lava descending from the cone.

The chief stream was the one that flowed from the great north fissure in the cone from the bottom of the Atrio del Cavallo below, and seemed to have been the event of the emptying of the funnel of its load of lava from base to summit.

This new eruptive orifice began to show itself on the night of Thursday, in the northern part of the Atrio del Cavallo, and was the scene of the sad catastrophe to a crowd of spectators on Friday morning.

The deluge of lava burst forth at this spot on Friday morning at sunrise, and flowed out like the molten metal on tapping an iron blast furnace, and filled the Atrio del Cavallo. This lake of fire reached to the south-east end of the Canal del Inferno, and nearly formed a vent there on the south slope of Vesuvius, above Pompeii.

Out of this gorge, down the mountain side, ran silently the sluggish stream, rolling over the gardens and vineyards, and along the roads, bursting through fences and walls, and submerging trees, till it reached the villages of Massa and Sebastiano.

By the next morning it had flooded these places, and made its way between them, breaking down houses, entering the streets, and filling them up half way, and setting fire to the combustible parts on each side. All the inhabitants had fled for their lives already, though several were reported to have been engulfed and killed, but most of the property left behind was destroyed.

The progress of the stream of lava through the inhabited country could be seen from Naples by the flashes of conflagration and the vaporous white steam hovering over the course of the lava. From these villages the lava mass spread out into a vast field of smoking slag and scoria.

These lava streams appeared as high embankments of rough black stones, or large masses of coke, piled one over the other to heights of twenty or thirty feet, and up which sides one had some difficulty in mounting. Then you stood on the edge, and overlooked a jagged level of smoking slag, hot to the feet, and emitting stifling fumes of hydrochloric acid gas.

On the banks and surface of these rivers of fire were formed small craters, or *fumaroli*, for the special use of the lava, underneath, which thundered like the Great Crater,

and launched forth smoke, ashes, and stones to the height of 70-80 metres, or 229·5 - 262·2 feet.

The next destructive phenomenon of the eruption was the shower of ashes, dust, scoria, and stones, which began, by degrees, on Friday, but did not show generally till Sunday, April 28th, when the lava had begun to cease flowing.

These showers consisted of the ash of incineration, and the burnt fragments of lava rocks, or scoria, which were frequently ejected red hot from the Crater, like rockets, and illumined the darkness of night.

The area over which these showers fell was very extensive, and varied according to the direction of the wind, and they were a source of danger both from the depth of the deposit, as well as from the weight of the projectiles, and their combustible power.

The dust and ashes fell in Naples one or two inches thick, and the shower was so dense as to obscure progress through the streets, and render the carriage of lanterns for walking about a necessity, and gas to be used in the houses for illumination.

The clatter of hoofs and the rumbling of wheels could not be heard on the pavements; in fact, it was just like a heavy fall of grey snow of a dingy colour, and it had to be swept up like it, and piled in heaps in the streets previous to removal.

It lay also on the roofs of the houses, and had to be dislocated from them by spades and shovels, and sent down into the courts below, like avalanches of snow, many of which courts, on May 8th, were still reported covered with ashes.

The whole atmosphere of the country got dimmed for miles around for nearly a week, and as the pillar of cloud from the Crater began to shrink, and the flame at night less brilliant, so the showers of ashes dwindled down, and finally ceased.

Professors Tinno, Catalano, Montano, Jannario, and Ceppola found, on analysis of the ashes, that they contained chiefly, insoluble silicates of alkalies and earths, and soluble chlorides of sodium and iron; and, in small quantities, sulphates of soda, magnesia, and alumina, and chlorides of ammonium and lead, with some free sulphur, and they were acidified by hydrochloric and sulphuric acids. Not the slightest trace of sulphuretted hydrogen or of arsenical compounds are stated to have been found in the ashes of this eruption, as has occurred on some previous occasions.

The pillar of cloud on the summit of Vesuvius is the invariable manifestation of action in the volcano, and is a conspicuous object by day in a clear sky, and the pile of flame at night, that casts a reflection over the sea of the Bay of Naples.

It began to rise on Tuesday, and by midnight it had fully formed, when great volumes of fire and smoke issued forth from the Crater and ascended into the sky. On Wednesday it was a fleecy, clear white cloud, ascending in great folds and gyrations, which spread out horizontally on the top, and increased in amplitude at the great climax of Friday, the 26th April.

It is supposed then to have obtained a most remarkable elevation and dimensions, not witnessed for a very long period (since 1779, by Sir W. Hamilton, four times the height), and has been estimated to have been three or four miles high, or from 16,000 to 20,000 feet, with a diameter increasing from below to two miles at its crest. When fully formed, it appeared like a huge pine tree or mushroom growing out of the mountain, and it expanded at its summit into a great umbrella like disc.

It would be altered in shape by the prevailing wind, and be lengthened out into a long cloudy banner floating away to leeward for 8-10 miles, and vanishing into fleecy mist in the distance.

After Friday, the 26th April, it began gradually to sink in height, and its clear and fleecy outlines were obscured by the fogginess of the dust showers, and by Sunday, the 28th April, its beauty of form and splendour of colour had disappeared.

The pile of red and yellow flames emitted from the Crater began to be very striking on Wednesday, the 24th April, and continued for several nights afterwards to illuminate the Bay of Naples.

Amongst the rolling clouds of the pillar may also be noticed dark clouds, formed by emissions of ashes and dust, projected from various orifices on the cone, and by the main Crater, by the sudden blasting of rocks and lavas by the explosion of steam, and gases in the beds of lavas. After the dust showers commenced, the height of the pillar of cloud is reduced, and may be estimated at about one mile (5280 feet), and then its terrestrial surface becomes foggy, and the scenery of the volcano and country around and underneath it darkened and obscure.

The following is a summary of the remainder of Mr. Black's remarks :—

Observatory.—This is situated on Monte Canteroni, which divided the two streams of the northern lava, and was consequently exposed the whole time to the scorching heat and mephitic vapours of the slag running red-hot past it on each side, as well as to the showers of ashes and scoria on its roof, which also rattled with the fall of the bombs and splinters of rock. Professor Palmieri and his assistants were therefore entitled to every meed of praise for their heroic resolution to abide by their instruments, and watch the progress of one of nature's grandest exhibitions.

Vegetation.—Everything organic was of course destroyed under the huge banks of the lava streams, but much more serious and more extensive destruction to agriculture and

horticulture was effected by the dust showers. Most of the vineyards and market gardens round Vesuvius for several miles were buried, and immolated by the acrid dust, especially when the rains came and washed it down afterwards into mud.

Cone and Crater.—The Great Cone was split open all along its north side from the top to the bottom, and let out of the fissure the great flood of lava into the Atrio del Cavallo, and was likewise cracked on the south side, to let out the south stream of lava. The Crater was wholly altered from what it had been before, and was now converted into a pit 600 feet deep, divided into two halves, east and west, by a wall of rock, that had fallen across during the throes of the volcano. A new Crater was formed in the Atrio del Cavallo, and poured out extra supplies of ashes and vapours between the cliffs of Monte Somna and Monte Canteroni.

Meteorological Phenomena.—The weather, prior to and during the first half of the eruption, was fine and clear, but subsequently thunderstorms and showers of rain prevailed uninterruptedly for several days. These rains washed the country all round of the deposit of ashes, cleansed the streets and houses of Naples, and the roads and trees in the country, but occasioned damage in low lying parts from the accumulation of *débris*. There was a splendid display of electric flashes in the pillar of cloud and in the dust clouds, besides the lightning of the thunderstorms, and it was beautifully seen at night, and was of a very dazzling description.

Sea.—The Bay of Naples continued calm throughout the whole period of the eruption, though the ships in the harbour were somewhat affected by the inland earthquakes.

Acoustic Phenomena.—These were of the most extraordinary and violent description, and frightened the inhabitants, and were called the roaring and bellowing of the volcano, and

were most terrible during Saturday 27th, Sunday 28th, and Monday 29th, and must be distinguished altogether from the thunder of the storm-cloud.

Property and Life.—Two very distressing events happened to the populations—one was the appalling loss of life to excursionists from Naples on Friday morning 26th, when the floor of the Atrio burst open, and a deluge of lava overwhelmed and destroyed them; the other was the destruction and submergence of the villages of Massa di Somma and Sebastiano on Friday, by the north-west stream of lava, and these were really towns of several thousand inhabitants each, and had good houses.

General Flight of the Population.—All the towns round the base of Vesuvius were early deserted by their inhabitants, who fled in thousands into Naples and to the further country, and left their property unprotected—such was the intensity of the panic.

Products of the Eruption.—The chemical products distilled and sublimated from the volcano this time were steam, muriatic acid, sulphur, chlorides of sodium, iron, copper, and ammonium, which became afterwards condensed on the sides and lavas of the mountain. The quantity and character of the solid projectiles were very remarkable, and consisted of bombs or globular masses, great pieces of rock and fragments of scoria, and many of these were seen red-hot in the pillar of vapour, and were projected the height of a mile above the Crater itself frequently.

Earthquakes.—Local ones occurred in isolated spots round the base of the volcano, and were especially noticed by the inhabitants of the villages, whose homes experienced their topical effects, chiefly on the north side of the mountain.

The paper was illustrated by a fine series of photographs, showing the appearance of the volcano from the first outburst to its final obscuration in the dust fog, the lava

streams in motion and cooled, and scenes of their devastation of houses, vineyards, and fields, as well as by charts and diagrams, and a large collection of minerals, obtained immediately after the eruption.

The CHAIRMAN said: Mr. Black has brought before us a very interesting and important subject. I am sure we are all impressed with the value of the communication, and the vast amount of trouble which Mr. Black must have had in taking all these photographs, and making the beautiful illustrations which are exhibited upon the screen, and which have been so admirably explained. It will not be my province to discuss the various points raised by Mr. Black, but I should have been glad if he had brought a little more prominently before the meeting his theory—if he has formed one—of the origin of volcanoes. He has alluded, incidentally, to the admission of water by fissures into the heated interior of the earth, and the gas resulting from its contact from the heated matter, causing steam and producing these eruptions. I know that was and still is a popular —perhaps the most popular—view of the origin and cause of volcanoes. Whether it can be sustained by scientific investigation, however, I am not able to say. It has always seemed to me, as suggested by Mr. Black in the paper, to be a puzzle how water can, by any possibility, have attained to the depths necessary to produce the effects, considering the heated character of the matter with which it would have to come in contact. Taking into consideration all the circumstances of the case, it appears to me that the supposition of the existence of fissures capable of admitting water from the sea, to the depth required, is one difficult to entertain. If there is a tendency to explode, or to send out molten matter from the interior of the earth, one would suppose that this pressure exerted

in the interior would prevent the admission of water, and so prevent the generation of steam, and the eruptions which are said to be consequent thereupon. But I do not wish to enlarge upon this question. Perhaps some gentlemen present may, taking up the hint that I have dropped, enter further into the discussion, and illustrate the matter more fully. The reports, so graphically described by Mr. Black, may arise from the passage of the vast quantity of steam—which undoubtedly does issue from volcanoes in times of eruption—with great rapidity through the atmosphere.

Mr. WATERS moved, and Mr. PLANT seconded, a vote of thanks to Mr. Black, which was unanimously passed.

The CHAIRMAN having intimated that the subject was open for discussion,

Mr. WATERS said the only feature of importance which struck him was that mentioned by the Chairman—namely, as to the action of water in producing volcanoes. The entrance of water was considered—among the theories which had yet been received—to have played a most important part, but not to have been the whole cause, of the production of volcanoes. Mallet's theory, which was the latest, and seemed to be generally accepted, was, briefly stated, that the heat which caused volcanoes was produced by the contraction and giving way of the solid crust of the earth to a certain depth; but the depth was not so great as to render impossible the penetration of water, which, in the form of steam, played an important part in the volcanic action. There was another point of some interest, with regard to the fine sand that Mr. Black had exhibited. It had been considered by some of the German geologists, and, he believed, also by Palmieri and other Italians, that the sand was produced by the attrition of the blocks which were ejected from the mouth

of the volcano. That was, in the opinion of competent observers, the explanation of the sand.

Mr. Black, having acknowledged the vote of thanks, said he had not devoted much attention to the theories of volcanic action, but he saw no reason to disagree with the ordinary supposition, that volcanoes were connected with the centre of the earth; and with regard to the presence of water at great depths, he saw no reason why it should not find admission through fissures similar to those with which everyone was familiar in great deposits of limestone. The difficulty was to account for the presence of the metals, lead, iron, and copper, in the lavas. The fresh and old lavas were very different in appearance one from the other. The latter, when they were a few years old—had their cavities often filled with solid crystals, which were never found in the recently produced lavas.

The reading of Mr. Black's paper having occupied all the time usually given to the meeting, it was put to the members, and carried, that the following papers announced on the circular for reading at this meeting be taken as read, and printed in the Transactions:—

The first paper was by Mr. J. Plant, F.G.S.,

OBSERVATIONS ON TWO PAPERS, by Rooke Pennington, Esq., LL.B., "On the Ossiferous Deposit at Windy Knoll, near Castleton;"—*Proceedings of the Literary and Philosophical Society of Manchester*, October 6th, 1874; and "On the Bone Caves in the Neighbourhood of Castleton;"—*Quarterly Journal, Geological Society of London*, February 10th, 1875.

This paper was subsequently withdrawn from being printed in the "Transactions" by request of its author.

RECENT DISCOVERIES IN THE ALLUVIAL DEPOSITS OF THE IRWELL IN SALFORD.

By John Plant, F.G.S.

After describing the geological features of the Irwell valley, Mr. Plant said that in this locality he had not been able to find many evidences of the occurrence of bones of extinct mammalia, or of stone weapons of the pre-historic ages in the gravels; though, as yet, there was nothing that could be urged against the possibility of finding such articles, as these gravels were correlated to the old valley gravels of the rivers of the South and East of England, where both bones and weapons were abundantly found. The only features of interest which he knew of as being contained in the gravels and sands were the occasionally occurring deposits of black vegetable silt, with great numbers of the common hazel nuts, and, at rarer intervals, logs of good, sound, black-stained oak. Of these latter there had recently occurred a remarkable instance in Lower Broughton, where three fine logs were found lying within a distance of thirty feet, and in another case—a few years ago—one was found about 300 yards to the south, at Hough Lane. One of these three logs had been brought to the surface, and, when measured, found to be about twenty-five feet long, with a diameter at the thickest part of the bole of twenty-two inches. It was entirely denuded of its bark, and had evidently been broken away from the roots; and all the smaller branches had been broken off. The colour was purplish-black, the wood sound throughout, and the boles filled with clean iron-stained sand and gravel. The other two logs were not brought out from the gravel, as they did not lie in the path of the sewer. The depth of the loam from the surface was six feet at the point where the oak logs were lying. Then came two

feet of gravel, under which lay the log that was exhumed. The full depth of the gravel below was not ascertained; and it was of but little consequence, as these gravels varied in depth in a very capricious manner, in some limited areas it would be found filling a deep cavity worn in the red sandstone. These oak logs presented no evidence of their having grown on the spot; in fact, their condition, as smooth denuded logs lying in the clean gravel, suggested but one conclusion—that they had been drifted about in the water for a long time before they were embedded in the gravel; and it was quite probable that many other such logs were yet hidden under the gravels of Lower Broughton. His conclusion as to the origin of the logs was based upon the knowledge that on the high moors of the Lancashire hills to the east of Manchester there were extensive deposits of peat, and not unfrequently the peat cutters met with logs of timber buried deep in the peat—oaks most frequently—and it was quite reasonable to suppose that in the floods which in Pleistocene times swept over the hills and down the valleys, the logs were washed out and borne away to the estuaries below, and were soon buried in the beds of gravel then accumulating.

Mr. Plant also said that in the progress of cutting the deep tunnel to form the intercepting sewer through the borough of Salford, several interesting features in the beds of the Bunter sandstone had been made known, especially with respect to certain faults, which at a future meeting he hoped to be able to describe. The subsidiary sewers to the great tunnel were cut at a higher level, and were mainly cut through beds of till clays, gravels, and rough sands, here and there passing through projections of red sandstone that stood somewhat higher than the average level of other beds, also covered by till. The upper surface of the beds of sandstone, wherever they could be examined under the freshly-

excavated clay, were deeply scored with ruts and grooves of glacial origin, such as were prominent on the sandstone at Ordsal Clough,* or else eroded into irregular hollows and long troughs, ploughed right across the beds; and the well-defined terrace of the old river valley eroded through the new red sandstone beds, before the deposition of the till, as frequently shown in these recent excavations. In cutting a deep sewer from the high ground through the low-lying meadow land near Ordsal Hall, the men found a limited deposit, at a depth of twenty feet, of sharp, greyish sand and silt, in which were pieces of oak, birch, alder, and hazel boughs, with quantities of hazel nuts, all deposited in one of these hollows in the new red sandstone; but the place was at least a quarter of a mile from the present river bed, and close to it was an enormous glacial boulder of hornblendic trap, weighing at least *seven tons*, with a highly polished glaciated surface. This rested upon the red rock, but there was no doubt whatever that it was originally surrounded by till clays, which had been washed away by the waters that had also afterwards deposited the alluvial sands, gravels, and loams which were now seen filling up the wide old river valley to a depth of many feet at this place. The existing terrace bank of the till deposits was now about fifty yards from the spot where the boulder was found.

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* *Vide* Tran. Geo. Soc., Man., Vol. vii. p. 40, for an account of the glacial marks on sandstone at Ordsal Clough.

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